INTERNATIONAL
Chemical Engineering
and Process Industries

Vol. 32, No. 10 — OCTOBER 1951

CONTENTS

TOPICS OF THE MONTH ... 467
FAWLEY—EUROPE'S BIGGEST OIL REFINERY ... 471
I.C.E. REVIEW:
HEAT TRANSFER *by F. P. Stainthorp, B.Sc.Tech., A.M.C.T., A.M.I.Chem.E.* ... 473
CORROSION PROCESSES AND THEIR PREVENTION ... 475
HANDLING ACETYLENE UNDER PRESSURE IN CHEMICAL REACTIONS *by S. A. Miller, M.A., B.Sc., Ph.D.* ... 476
X-RAY ANALYSIS OF PETROL ... 478
LAMINATED PLASTICS (Book Review) ... 478
ACETYLENE MANUFACTURE AND UTILISATION IN GERMANY ... 479
GRAPHICAL REPRESENTATION OF EXTRACTION PROCESSES *by A. V. Brancker, Ph.D.* ... 482
MONSANTO'S NEW WORKS IN SOUTH WALES ... 485
POWER-GAS CELEBRATE 50 YEARS OF CHEMICAL ENGINEERING ... 487
U.S. CHEMICAL STATISTICS (Book Review) ... 488
CHEMICAL ENGINEERING COSTS (Book Review) ... 488
BRITISH TITAN'S NEW LABORATORIES ... 489
RECENT PUBLICATIONS ... 490
WATER IN INDUSTRY ... 491
RECENT AMERICAN CHEMICAL ENGINEERING PATENT CLAIMS ... 493
NEW PLANT AND EQUIPMENT:
Clip-type valve; High-performance refractory; Silver-lined M.S. plant; Portable blowers ... 494
WORLD NEWS:
From Great Britain; Austria; Germany; Irish Republic; Italy; France; Argentine; Australia; Japan; Philippines; Belgian Congo; Canada; India; U.S.A. ... 495
THE SCIENCE OF COAL (Book Review) ... 497
MEETINGS ... 498

Subscription rates: 1 year 4 dollars, 3 years 8 dollars, paid in advance
England: Leonard Hill Limited, 17 Stratford Place, London, W.1 *U.S.A.: British Publications Inc., 150, East 35th St., New York, 16*

Topics of the Month

Industrial power from the atom

As pointed out in these columns in July (p. 313) an investigation has begun in the U.S. of the feasibility of constructing an atomic pile which would produce both plutonium and electric power for industrial use. Recently we had the pleasure of meeting in London the author of this scheme, Dr. Charles A. Thomas, president of the Monsanto Chemical Co. Inc. Dr. Thomas told us that he had long urged a study of the possibility of linking the Government's Atomic Energy Commission with private enterprise in this nuclear power station scheme. He explained that it would not be economic to build an atomic plant to produce power alone. One of the main reasons for this is that at present such a plant would cost something between two and three times more than a comparable coal, oil or water power plant. Furthermore, there are legal difficulties, because in America no private company is allowed to own fissionable material. Thus a partnership between Government and private industry is necessary.

When the scheme was first proposed to the Atomic Energy Commission they doubted that private industry would be interested. In fact, Monsanto and the Union Electric Co. very quickly signed an agreement with the Commission to investigate the feasibility of such a project and now there are eight companies interested in the investigation.

If these preliminary feasibility studies are favourable, the next step is for the private firms concerned to design a plant to produce plutonium and power. The final step will be for the Government to give industry a satisfactory contract for the purchase of plutonium produced by the plant because, of course, it would be economical only if there was, say, at least a ten-year agreement for the purchase of this material.

The principle of such an atomic power plant is simple: the high temperatures which develop in an atomic pile during the conversion of uranium to plutonium would be captured by a heat-transfer medium and passed through a heat exchanger where steam would be produced which, in turn, would be fed into ordinary turbines to operate electrical generators. However, the design of such a plan poses a multitude of chemical engineering problems. For in-

stance : Are there constructional materials that can withstand these very high temperatures for long periods ?

What material can be used as a heat-transfer medium ?

Will the heat be radioactive and will this radioactivity be transferred to the steam ?

If so, will the turbines stand up to it and what safety measures would be necessary ?

It is to be hoped that it will eventually be found possible to construct a nuclear power station. Apart from the obvious fact that it would mean the beginning of the exploitation of a valuable additional source of power, the utilisation of atomic energy for purposes other than military would have a great moral effect throughout the world and might one day make it possible to organise effective international control of atomic energy.

Outdoor chemical plant

THE principal advantages of outdoor chemical plants over the more conventional indoor plants are lower capital cost, easier accessibility for maintenance of equipment, reduced explosion or fire hazards and improved facilities for modifications and enlargements. Their chief disadvantage is that they require more insulation and protection against weather.

The experience gained with large outdoor petroleum-refining installations is being applied to other chemical plants as shown by the successful operation of such plants under extreme climatic conditions in Canada and the U.S.A.

Since Britain has a fairly temperate climate without excessive extremes of heat and cold, it would seem ideal for the location of outdoor chemical plants.

According to a discussion in *Chemical Engineering Progress*, there are two major requirements for successful outdoor operation.

The process must allow instruments, controls and facilities requiring regular attention to be grouped in a control-house which is enclosed for the protection of operating personnel.

In addition, without itself requiring shelter, equipment must protect the materials being processed from the effects of weathering. Outdoor plant design lends itself particularly well to automatically controlled continuous operations involving preferably the treatment of liquids and gases as opposed to solids.

It is claimed that, in spite of the increased cost of insulating an outdoor plant, total expenditure is 10 to 12% less than for a comparable indoor plant. Of equal importance in these days of shortages is the saving of building materials made possible with outdoor plants.

Raw material prospects a little brighter

ALUMINIUM, lead, tungsten and molybdenum supplies in the U.K. are now somewhat better than was anticipated when the rearmament programme first got under way several months ago. In the case of zinc and nickel, however, the position is still serious.

According to the Board of Trade, the supply of aluminium is now better than the average monthly rate for 1950 and the increase of 2,000 tons/month in the allocation to fabricators of wrought metal has been made possible by a long-term contract with the Aluminium Co. of Canada. This improvement should enable fabricators to meet defence demands without interfering with essential civilian orders. Lead supplies should be sufficient to maintain the present rate of delivery to consumers this year and next, if there are no more shipping difficulties. The acute shortage of tungsten and molybdenum should also be eased by the allocations announced by the International Materials Conference. On the other hand, cuts in the level of zinc allocations will have to be continued at rates ranging between 20 and 50%. The use of nickel or austenitic stainless steels in the manufacture of certain items and the nickel plating of some items are now prohibited, as there has been no change in the supply of nickel, which remains uncertain.

As was stated in our August issue, the procurement of all non-ferrous metals and several other basic raw materials is now the responsibility of the Ministry of Materials, who in some cases are acting as the sole importers. Their task is not only to buy raw materials but also to develop alternative manufacturing processes and exploit new resources.

The least that can be said is that raw material supply prospects in Britain are no worse than was anticipated. It must be hoped that, as in the case of sulphur, referred to elsewhere in these notes, vigorous measures will progressively overcome present scarcities.

Full speed ahead for German industry

POLITICAL considerations are causing a progressive relaxation of control over West German industries with war potential which would have been unthinkable two or three years ago.

All prohibitions and limitations have been lifted from the manufacture of chlorine, synthetic ammonia, styrene and butadiene. Aluminium, magnesium, synthetic petrol, oil and lubricants are other products no longer subject to control.

Synthetic rubber is yet another critical material for the production of which the Germans have received the 'all clear' signal. Indeed, American senators are urging the restoration and expansion of the German synthetic rubber industry. They point out that before the last war Germany had developed a synthetic rubber industry with a peak capacity of 74,000 long tons p.a. of all types. Within a few months, it is estimated, these plants could be reactivated and be producing at an annual rate of 7,000 tons and possibly at a rate of 35,000 tons p.a. after eighteen months of rehabilitation.

Productivity in the pharmaceutical industry

THE American pharmaceutical industry is the biggest and most productive in the world and has to its credit the pioneer large-scale manufacture of many famous drugs: penicillin and the other antibiotics, synthetic vitamin A, the anti-histamines, synthetic anti-malarials and, most recent of all, cortisone and ACTH, the anti-rheumatic hormones.

However, it was not American technique in bulk manufacture of drugs but rather their methods in conventional pharmaceutical processing that were the objects of study of a British productivity team which toured the U.S. pharmaceutical industry at the end of last year and who issued their very comprehensive report last month (Anglo-American Council on Productivity, 3s. post free).

Measured against its American counterpart, the British pharmaceutical industry compares not at all badly. In basic factory organisation the British have little to learn. Furthermore, executives and operatives probably work harder than their counterparts in America. It seems, therefore, that in fundamentals, the British industry can

hold its own with the American. Yet, generally, American pharmaceutical productivity is higher.

The reason for this is that the Americans have been able to organise manufacture into long runs of a smaller range of products than that made by comparable British manufacturers. Two circumstances have favoured this: (1) a big and expanding home market which buys nine to twelve times the amount of branded specialities than is bought in Britain; (2) absence of a pressing need to export a large part of their output with all its production-slowing snags.

It is in this climate of freedom to make and sell what they like and build their factories where they like that the Americans are able to produce more than the British. It is difficult to see how this climate can be created in Britain. The two biggest customers of the British pharmaceutical industry are the Ministry of Health which, to put it mildly, hardly favours branded specialities, and the overseas buyer who just cannot be ignored, difficult as it might be to satisfy his scores of special needs. In short, the needs of both big customers are against few products and long runs, the main pre-requisites of high productivity.

This does not mean that British manufacturing chemists must despair of achieving higher productivity. They might well improve their cost control, use more mechanical handling, apply engineering more to production problems and improve the organisation of maintenance work, to mention only a few of the ways in which the Americans excel. A great deal can also be done to improve packaging methods and close collaboration with the makers of packaging machinery and materials is urged by the team.

There are, indeed, many things that can be learned from the Americans and this excellent report should be thoroughly digested by everyone who can in any way influence pharmaceutical productivity. But, as pointed out by our contemporary, *Manufacturing Chemist*, in a summary of the report, the team did not find everything in America above British standards; in several respects, some important, American practice is inferior. Lastly, it should not be overlooked that, in spite of the high productivity of the American pharmaceutical industry, a great many of its products cost more to buy than comparable British products.

German chemical plants for India

INDIA'S war reparations from Germany include a methanol plant, a T.N.T. factory, a glycerin plant, a precision machine tools manufacturing factory and an electric steel smelting furnace. All these plants have been allotted to India as complete units and can be utilised as self-sufficient producing factories.

The methanol plant, from Badische Anilin und Soda Fabrik, Ludwigshafen, is valued at Rs. 530,282 and is designed for the production of methanol from the stage of compression of raw methane gas to the synthesis of 90 tons of pure methanol in 24 hr. It is capable of producing 20,000 tons of pure methanol p.a. if it is balanced by a fractional distillation unit.

Valued at Rs. 174,888, the T.N.T. factory is capable of producing 12 tons of T.N.T. in 24 hr. at the rate of 4 tons/charge and 3 charges/day. This plant has been retained for use by ordnance factories.

The glycerin plant, valued at Rs. 69,001, is meant for vacuum distillation of raw glycerin whereby pure glycerin suitable for nitration is produced. It is capable of producing 80 tons/month of pure glycerin.

Towards a glut of sulphur?

INTEREST throughout the world in new measures to increase sulphur output continues undiminished and almost every day there is news of projects for winning more brimstone or for producing sulphuric acid from other sulphur-bearing materials. In Britain details have been given of the projected anhydrite acid plant of the United Sulphuric Acid Corporation Ltd., which is to be erected at Widnes. Costing £4,200,000, it is scheduled to begin production in four years of 150,000 tons p.a. of sulphuric acid from indigenous supplies of 240,000 tons of anhydrite p.a. Cement will be a by-product of the process and the Associated Portland Cement Co. Ltd. is to build a factory near the acid plant to manufacture about 140,000 tons of cement p.a.

In the United States the Bureau of Mines believes there are good prospects of overcoming the sulphur shortage within the next few years. Among the chief reasons for this prediction is the discovery by the big American producer, Freeport Sulphur Co., of a new deposit of sulphur at Garden Island Bay at the mouth of the Mississippi, 100 miles south-west of New Orleans. Freeport will build a mining plant at a cost of between $10,000,000 and $15,000,000 to work the deposit and hopes to have it working within two years with an eventual output target of 500,000 long tons of brimstone p.a. The Bureau lists the discovery of three other new deposits of brimstone in the U.S. as an additional reason for their prediction of a reasonably early end to the sulphur shortage. Other reasons are increasing production of sulphur from oil refinery gases, as sponsored by the Petroleum Administration for Defence, and increased output of sulphuric acid from smelter gases, pyrites and other sources.

Looking abroad, the Bureau can find other evidence of a progressive narrowing of the gap between sulphur supply and demand. In Ecuador (as reported in INTERNATIONAL CHEMICAL ENGINEERING, August, p. 393) an American firm, Chemical Plants Corporation, proposes a substantial development of the Tixan sulphur mines in the Andes. These deposits are said to be at an altitude of only 8,000 ft., compared with the usual 12,000 to 15,000 ft. of other volcanic deposits in the Andes. In Mexico there is increasing production of sulphur from refinery gases.

While it is premature to state that the end of the sulphur famine is in sight, it seems fairly safe to endorse the U.S. Bureau of Mines' forecast of a substantial improvement in the position within the next few years. And after that, as we have before predicted in these notes, it is very possible that the world will suddenly run into a glut of sulphur.

Galvanising techniques: British and U.S. compared

IN the hot-dip galvanising industry the Americans do not appear to be technically ahead of their British counterparts but, generally, achieve greater productivity by more efficient work handling. This conclusion has been reached by a specialist team representing the British hot-dip galvanising industry who visited the United States last year and whose report has just been published by the Anglo-American Council on Productivity (3s. 3d., post free). Supplies of zinc were becoming scarce in the U.S. when the team arrived. Nevertheless, the Americans showed little interest in conserving supplies by reducing ash or dross formation. In this respect British galvanisers benefit from co-operative research, which is almost non-existent in the U.S.

The main distinction between American and British galvanising techniques is the almost exclusive use of hot sulphuric acid for pickling in the U.S. Though it has technical advantages, which are discussed in the report, and is, on the basis of acid equivalents, cheaper than hydrochloric acid, the latter is preferred in Britain because it does not need heating. Pickling is always followed by a water rinse and pre-fluxing, either in hydrochloric acid (in the older plants) or in a hot neutral flux solution. The advantages of a neutral flux are strongly emphasised in the report. Drying ovens are hardly ever used, the work drying sufficiently in the air for it to be dipped safely through the thick flux layer which is maintained on the entry end of the galvanising bath. All the work thus has to be passed under a weir or else twice dipped. No dry galvanising (*i.e.* without flux blanket) was seen. In view of all that has been written in the American technical Press about dry galvanising, this discovery is very surprising.

Several of the firms visited paid a little extra to get their zinc delivered in bundles, some of the bottom slabs having feet to facilitate handling by a fork-lift truck. The slabs were held together with steel tape, and each bundle weighed about a ton. At one plant it was said that 50,000 lb. of zinc had been unloaded in 2 hr. by one truckman and two assistants. If the ingots had not been palletised the job would have taken five or six men a full day.

The team were very favourably impressed by the extensive use made everywhere of mechanical handling devices throughout the galvanising process. Time and methods study engineers were employed in many galvanising plants and given full scope to develop their ideas in order to obtain maximum productivity, and much ingenuity was displayed in designing racks, cradles, jigs, etc. In specialised line production, where continuous runs were assured by large consumer markets, highly mechanised methods were used. For dipping general jobbing work innumerable ingenious handling devices are employed. Some of these are illustrated in the report. They were stored so that they could easily be found for further use, and there was no hesitation in making new tools to handle new types of work as they came in.

About half the firms seen were recovering zinc from zinc ash. The methods employed, which are simple and economical, are described. The recovery of zinc from dross was only being operated by one very large firm visited by the team.

Engineering research on metals

THE effect of high temperatures on metals, fatigue strength of metals and fretting corrosion are among the important investigations being carried out by the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research. The board was appointed in 1946 and its first meeting was held in May 1947. Since then it has moved to East Kilbride, Scotland, where it is building extensive laboratories and workshops. Last month the board's first report was published (Stationery Office, 2s. 6d.).

In the high-temperature studies, the gradual increase in the length of hot metals known as creep is being examined in two ways. Long-term research is intended to achieve a greater understanding of the underlying reasons for creep and short-term work to provide design data for such applications as steam and gas turbines.

Work on the fatigue strength of metals is being carried out with specimens larger than usual, because it is not possible to predict what will happen to larger components under repeated loadings from tests on such small specimens. Tests on specimens of up to 12 in. wide of high-strength aluminium alloy and mild steel sheet have shown that a $\frac{1}{16}$ in. diameter central drilled hole reduces the fatigue strength of the sheet to a much smaller extent than does a $\frac{3}{4}$ in. diameter hole. Similar work is now being done with high-strength magnesium alloy.

Fretting corrosion is the name given to the damage which may be done to the surfaces of two closely fitting components of a machine when there is a small movement between them. This movement causes roughness of the surfaces from which fatigue cracks can develop and lead to failure of one or other of the components. Previous work had indicated that the oxide layer on the surface of the metal was mainly responsible for fretting corrosion. Tests using gold, which does not oxidise easily, also resulted in severe damage to the specimens. This led to a re-examination of the earlier theories and to the conclusion that the phenomenon is primarily dependent on metallic contact, the effect being modified by the nature of any oxide film formed. Nickel or chromium plating of the surfaces produced little improvement, but recent tests on phosphated surfaces have given very encouraging results.

Education in the plastics industry

IN 1942 the Plastics Institute President's Fund was formed for the promotion of education within the British plastics industry. Since that time a great deal has been accomplished. In particular, scholarships and training grants have been awarded; support given to universities and technical colleges; a scheme of apprenticeship within the plastics industry instituted and a large number of monographs of scientific and technological subjects published.

Most of the income of the President's Fund was provided by seven-year covenants which have now expired and, in order that this work may continue and, if possible, be expanded, the trustees are launching an appeal for subscriptions to establish a new fund called the Plastics Industry Education Fund. This, it is hoped, will provide a minimum income of £4,000 a year for educational purposes. Intending contributors can make annual subscriptions under seven-year deeds of covenant, deducting tax at the standard rate of income tax in force from the gross annual payments under the deeds, or they can make donations in the ordinary way. From the point of view of the fund, seven-year deeds of the covenant are preferable, both because they provide an assured income and because the objectives of the fund can be regarded as charitable, so that the trustees will be able to recover the tax deducted by the donors.

A new deed is being drawn up to form a trust to administer the money received, and new trustees approved by firms who subscribe to the fund will be appointed. It is intended that the Plastics Institute shall be the executive body to administer the fund in accordance with the decisions of the trustees as to how the money is to be spent.

This appeal has the full support of the Council of the British Plastics Federation, the Council of the Plastics Institute and the trustees of the President's Fund of the Institute. It is hoped that all firms interested in the plastics industry will support the new fund to the fullest extent possible. Subscriptions may be sent to the trustees of the Plastics Industry Education Fund, c/o the Plastics Institute, the Adelphi, Adam Street, London, W.C.2.

FAWLEY—Europe's Biggest Oil Refinery

In 27 months, from July 1949 to September 1951, a new petroleum refinery has been built on a 450-acre site overlooking Southampton Water. This refinery, built and operated by the Esso Petroleum Co. Ltd., is by far the largest single project in Britain's refinery expansion programme and is the biggest refinery in Europe. Each year it will produce 6,500,000 tons of petroleum products, enough for more than a quarter of the United Kingdom's annual requirements. Here is a description of this £37,500,000 refinery which was opened by the Prime Minister on September 14.

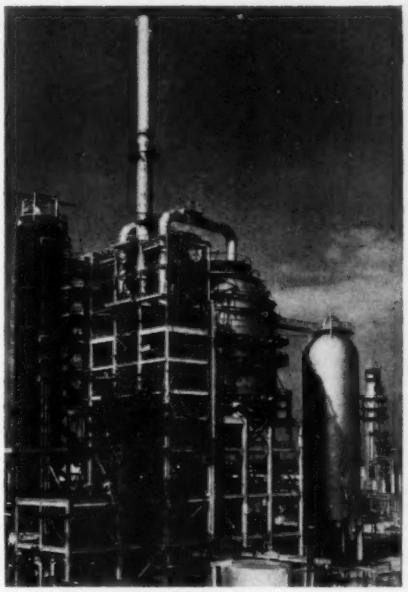
OF all feasible refinery sites in Great Britain, Fawley, near Southampton, was chosen as the most economical location in relation to the crude oil supplies of the Middle East, upon which the refinery will operate almost exclusively. Furthermore, it offers the shortest haul for the delivery of products to the largest consuming area, London, and the best outlet for locally consumed fuel products. Southampton is one of the finest harbours in the world and navigational and marine conditions at Fawley are ideal for all ocean, coastal and local tanker operations, very important considerations in view of the fact that all Fawley's crude supplies and the great majority of its products will be transported by sea. The berthing site is fronted by about 2,500 ft. of open navigable water and it is isolated from all other shipping activities. This isolation is an important safety factor in undertaking the large number of concentrated tanker operations involved. An ocean jetty already exists at Fawley and ample foreshore space is available for erecting four more similar berths, as well as accommodation for coasters, bunkering vessels and barges.

Construction at record speed

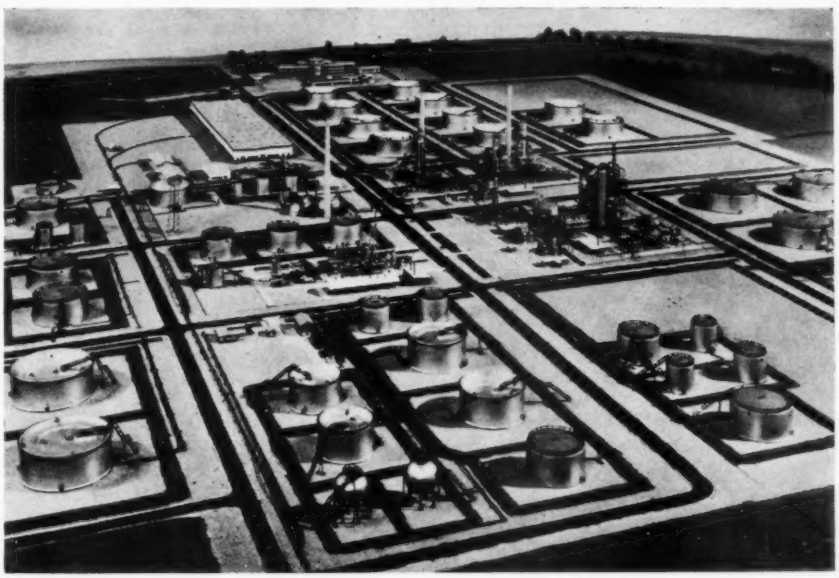
The Esso Petroleum Co. Ltd., formerly the Anglo-America Oil Co. Ltd., is the oldest of Britain's major oil companies. It has operated a refinery at Fawley for many years and this was one of the reasons for choosing this site for the new refinery. Planning began five years ago. Actual construction commenced in July 1949 and the refinery was completed in September 1951, four months ahead of schedule. A great concentrated effort has been needed for this very creditable achievement. At the peak of construction more than 5,000 men were working on the site. A permanent staff of 2,500 will run it.

Main contractors

Although the main contract for procuring the major units and for their erection was placed with the Foster Wheeler Corp. in the U.S., the actual work has been executed by Foster Wheeler Ltd., a British affiliated company. Very large subcontracts were placed with U.K. firms, including Whessoe Ltd., John Laing & Son Ltd. and Wm. Neill (St. Helens) Ltd. So far as possible British materials and plant have been used and, indeed, some two-thirds of the total expenditure has been with British firms. It has, however, been necessary to obtain the major refinery units such as the catalytic cracking plant, the pipe stills, the Edeleanu plant and some of the feed plant from the U.S. In some instances it would not have been possible to get certain plant items from anywhere else except America. Furthermore, in some cases, only American manufacturers could supply the plant without delay.



The catalytic cracking plant which will soon produce 1,000,000 gal. day of motor spirit.



Model of the new Esso refinery at Fawley, built to a scale of $\frac{1}{32}$ in. The administration buildings are in the centre of the far background. The long flat building just to the left is the giant maintenance shop. Many of the tanks hold 20,000 tons of crude oil.

Fawley's products

Of the 6,500,000 tons of petroleum products which will be produced annually at Fawley, the most important will be high-grade motor spirit which will be turned out at the rate of 1,000,000 gal./day. Other products will be: solvent naphtha, white spirit, tractor fuel, fuel for jet aircraft, kerosine, high-speed diesel oil, light industrial diesel oil, gas oil for the enrichment of ordinary coal gas, marine diesel oil, lubricating oils, light fuel blending stock, bunker fuel oil, asphalt and liquid petroleum gases. An important by-product of the refinery will be 99.5% chemically pure rock sulphur derived from hydrogen sulphide. The plant for treating the H_2S is now under construction and, when operating in 1953, will produce 12,000 tons of sulphur p.a.

The refinery units

The major units are two pipe stills, a catalytic cracking plant with light ends and polymerisation facilities, and an

Edeleanu plant for sulphur dioxide treatment of kerosine and gas oil.

Fractional distillation

Fractional distillation of crude oil is performed in the pipe stills. The oil, previously heated to temperatures up to 750°F. in the pipe-still furnaces, is flashed as vapour into a fractionating tower where the various components condense at different levels on bubble trays. There are three fractionating towers. Two operate under atmospheric pressure and the 'bottoms' from these are transferred to the third tower for vacuum distillation. Steam is introduced to reduce distillation temperature.

Catalytic cracking

The next major step is catalytic cracking of gas oil from the fractionating tower. Fluid catalytic cracking, whereby the catalyst flows continuously with the oil vapours and is automatically regenerated, is employed.

Lubricating oil plant

Lubricating oil and motor spirit from the fractionating tower are converted into high-octane spirit plus a certain quantity of gas, by heat and pressure but without a catalyst in a thermal cracking plant.

The octane rating of the petrol obtained by distillation is increased by polymerisation, the process which is the reverse of cracking.

Purification plants

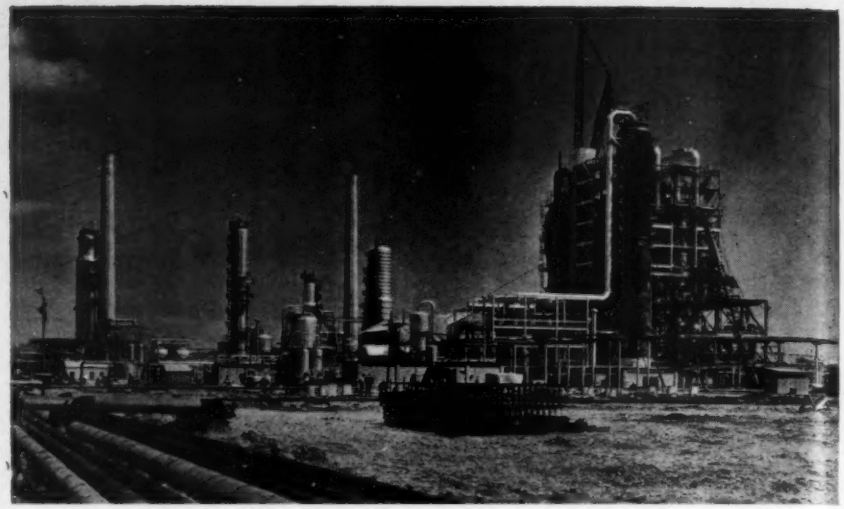
After distillation and cracking, the various petroleum products are purified in a number of plants, using acids, clays, solvents and various other chemicals. Perhaps the most spectacular of the purification plants is the 113-ft.-high debutaniser tower which weighs 135 tons. It removes butane and other light gases from the motor spirit so that it meets the required vapour pressure specification.

Another purification unit is the copper-sweetening plant. Motor spirit from the fractionating towers is transferred to this unit where corrosive compounds and unpleasant vapours are removed. It is then blended with high-octane spirit from the cat cracker.

Edeleanu unit

The burning qualities of kerosine from the fractionating tower are improved by chemical treatment in the highly specialised Edeleanu plant. Unpleasant smelling sulphur compounds are removed from the kerosine in a hypochlorite plant which treats turbo-jet fuels similarly.

There are four plants for the treatment of heavy lubricating oil: the propane deasphalting plant washes the lubricating oil and removes asphalt; the phenol extraction plant removes aromatics which have poor lubricating qualities; the propane dewaxing plant crystallises out the wax, which is then filtered and returned to the cat cracker; and, finally, the clay treatment plant improves the colour of the lubricating oil and gives it its characteristic green fluorescent appearance. Anti-corrosive additives for lubricating oil are manufactured in a special plant which reacts chemicals with a lubricating oil base.



General view of the main refinery units at Fawley.

Hydro-desulphurisation

The sulphur content of tractor fuel is removed in a hydro-desulphurisation plant. In this plant, fuel from which sulphur has been removed is mixed with hydrogen and passed over a bed of catalyst. The stream of H_2S from this plant is then fed into the sulphur plant. The sulphur plant, previously mentioned, will, when completed, take the stream of H_2S from the desulphurisation plant.

Oxidising and gas compression

Finally there are the oxidising plants, in which air is blown through bitumen to produce a rubbery substance which has special uses, such as roofing felt, and the gas compression and separation plant. This latter plant takes gas from the fractionating tower and removes from it all recoverable material, which is condensable at ordinary temperatures. The treated gas is then fed into the refinery fuel mains for use in furnaces.

The maintenance building

This building, 800 ft. long and 180 ft. wide and covering more than three acres, is the largest refinery maintenance building in Europe. It houses one of the most up-to-date and well-planned machine tool shops of the country. It contains travelling cranes and a modern system of ventilation and lighting designed for the comfort of the workers.

Marine terminal

This 3,200-ft.-long jetty is one of the longest oil jetties in the world and it is big enough for the berthing of four 26,500-ton tankers simultaneously. More than 600 piles, 71 ft. long with a cross-section of 16 in. by 14 in., form the foundations of the 2,000-ft.-long approach over the salt marsh. This approach carries a great number of oil and steam pipes arranged in two tiers, as well as a 4-ft. diameter salt-water pipeline. A road for motor traffic and a pathway run alongside.

On the shore side of the jetty is a pump-house supplying 50,000 gal./min. of salt water to the refinery for cooling the units.

Materials used

Materials used in constructing Fawley included 100,000 tons of steel, 300 miles of steel, cast-iron and concrete pipes, 200 miles of electrical wiring, 100,000 cu. yds. of concrete, 1,600 lb. of mercury, 12,000 valves and 220 pumps.

Economic significance

The refinery represents an investment of £37,500,000. It is a private enterprise project, no Marshall Aid dollars being involved. It is estimated that when in full operation it will save Britain well over $100,000,000 p.a., that being the sum which would have to be spent to import a similar quantity of oil products as will be refined at Fawley.

Bearing in mind that before the war Britain had only negligible refining capacity and that in 1948 she refined only 3,500,000 tons, Fawley, with its capacity of 6,500,000 tons p.a., is indeed a magnificent achievement, an enormous stride forward to the planned British refining capacity of 20,000,000 tons p.a. which, it is hoped, will be reached by 1953.

Not the least remarkable feature of the refinery has been the speed with which it has been built. This would not have been possible without the excellent co-operation between the 70 resident American technicians and the 5,000 British, together with some Danes and Dutchmen, who worked on the jetty. Throughout the construction there were no labour disputes.

HEAT TRANSFER

Convection, fixed and fluidised beds, circulating liquids, condensation

By F. P. Stainthorp, B.Sc.Tech., A.M.C.T., A.M.I.Chem.E.

SINCE the last review was published (September 1950) two useful books have appeared. Eckert's 'Introduction to the Transfer of Heat and Mass'[1] is a useful addition and well illustrated. Numerous fully worked out design problems appear in 'Process Heat Transfer' by Kern[2] and, although directed particularly to the petroleum industry, it should prove valuable in the wider field. The number of papers published on the various aspects of heat transfer have, if anything, increased and, even though some dealing with certain abstract problems of unsteady state transfer have been omitted from this review, there are still some 58 which are of direct interest to the chemical engineer.

Conduction and insulation

Further data on the thermal conductivity of steam in the temperature range 100 to 350°C. and at pressures up to 150 atm. have been published by Keynes and Sandall.[3] Their results are somewhat lower than the previously accepted values published by Vergaftig and Timroth, although additional values for nitrogen up to the same pressure are in close agreement with these workers. Lindsay and Bromley[4] have developed an equation for predicting the thermal conductivities of gas mixtures from a knowledge of the physical properties of the pure components. Except for mixtures with hydrogen, the predicted values are within 2% of those determined experimentally. Some new values for the thermal conductivity of aqueous caustic soda and potash solutions up to 60% strength have been reported by Riedel,[5] who shows that the curves at different temperatures are parallel up to 80°C.

Beatty *et al.*[6] have developed an unsteady state technique for determining the thermal conductivity and diffusivity of poor conductors, *e.g.* plastics. A heat-flow meter for determining the loss from surfaces has been described by Hatfield and Wilkins.[7] It comprises a disc of tellurium-silver alloy with a copper gauze on each side and when placed against the surface the E.M.F. developed is proportional to the heat flux.

The heat loss from small-diameter pipes (¼in. to 1 in.) has been investigated by Laznovsky,[8] who confirms that even with good insulators the loss increases with thickness of lagging up to a maximum. He shows that losses are best reduced by treating the surface of the pipe.

Radiation

The Committee for the Study of Radiation from Flames has commenced to publish its deliberations. Professors Broeze, Ribaud and Saunders have outlined the scope of the work reported and the future trends. The problems and methods of the general research attack have been discussed by De Graef and Thring and the latest developments in a study of the radiation from luminous flames have been described by Comerford. These have so far appeared in the French journal,[9, 10, 11] but they are shortly to appear in the Journal of the Institute of Fuel. The temperature and gradients in a luminous carbon black flame have been measured by Jensen and Anderson,[12] who found that the maximum temperature (1,400 to 1,450°C.) was reached near the surface.

Penner[13] has developed an approximate method of estimating the radiant heat transfer from gaseous emitters which is accurate enough for most industrial calculations and Hottel[14] has described in detail the methods of estimating heat losses from various geometrical shapes. This article contains many illustrations of the techniques used.

An analysis of the use of radiant heating has been made by Landfermann, with special reference to the plastics industry. He shows that, whilst of little value for thermo-setting resins, the use of infra-red can be very valuable for thermoplastic coatings, particularly P.V.C.[15]

Convection

Sherwood[16] has reviewed the present state of the relationship between heat transfer, mass transfer and fluid friction, illustrating their interdependence when the latter is calculated in terms of the skin friction only. Empirical correlations are shown to be more reliable than the semi-theoretical ones. Deissler[17] has developed new equations for the velocity distribution in the laminar and boundary layers in smooth tubes and used these successfully to predict film coefficients at high Reynolds numbers. A general mathematical solution for the unsteady state transfer of mass or heat between two phases separated by a moving boundary has been prepared by Danckwerts.[18]

The fluid flow patterns in the shell side of baffled heat exchangers have been studied by Tinker[19] and these patterns related to the transfer coefficients. A further paper from Bergelin *et al.*[20] has appeared on their investigation into the design variables of shell and tube exchangers. They show that small-diameter tubes on staggered pitch give the highest efficiency and that, whilst increase of pitch for a given tube size reduces the pressure drop, it also materially reduces the film coefficient. A method of assessing shell-and-tube exchangers economically has been developed by Cardwell.[21] At fixed overall heat transfer rates he finds a sharp minimum cost at an optimum tube diameter for a given length or an optimum length for a given diameter. The total load then fixes the number of tubes. Heat exchangers for liquids of high viscosity pose special problems which are discussed by Rapoport,[22] and his conclusions are applied to the case of sugar-molasses mixtures.

Sohngen[23] has published a detailed analysis of the construction, capacities and applications of many kinds of heat exchanger constructed from carbon. The development of more efficient high-temperature gas turbines and low-temperature gas liquefaction units is leading to the production of compact and light gas-gas exchangers (or regenerators) capable of a high performance. Kays and London have described an all-embracing test rig for proving exchangers of the plate-fin and similar designs. Experimental results on many patterns covering transfer rates and pressure drops have been reported.[24] Aronson[25] has detailed the method of design of this type of regenerator and, with Sinpelaar,[26] reported an experimental evaluation of its performance, which reached 95% efficiency. Comparison of a large scale with a pilot model shows that the heat transfer rates are in agreement, but pressure drop across the full-size unit was larger than expected from the small-scale results. A unit, described by McMahon, is built up from perforated plates separated by neoprene gaskets. The gases jet through the perforations and impinge on the next plate, thus leading to high transfer rates at relatively low pressure drop.[27]

Heat transfer and pressure drop in annuli have been studied by Knudsen and Katz.[28] They worked first with a plain inner tube and then studied the effect of the height and pitch of spiral fins. Their results are correlated for the range Re 6,000 to 100,000 in terms of the conventional dimensionless groups with the addition of a ratio containing the principal variables of the fin dimensions. Some interesting flow patterns were observed when the outer tube was constructed from plastic and a dye introduced into the system. The temperature and velocity distribution in the wake of a heated cylinder has been system-

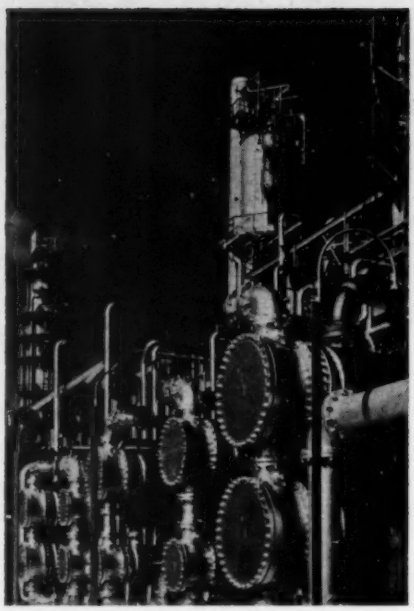
atically explored by Billman and co-workers.[29] Further work on transfer rates from fluids to the wall of a packed tube has been reported by Leva, who worked with tube to packing ratio less than three and found that the pressure drop was much lower than with a high ratio, although the film coefficient was not materially reduced.[30]

Fixed and fluidised beds

Several papers have appeared in the field covering heat transfer in fixed and fluidised beds. An analytical treatment by Singer and Wilhelm[31] covering fixed bed and moving bed exchangers and fixed bed reactors is made in terms of conduction through the solid particles, convection and conduction in the fluid, and particle-fluid transfer. Another mathematical treatment by Munro and Amundson[32] is confined to the particle-fluid problem and they show by examples that approximations tend to yield areas which are too small. Morales, Spinn and Smith[33] have explored the velocity distribution in beds packed with small cylinders. They find that the flow is far from uniform, having a maximum between half and three-quarters of the radius from the centre and falling gradually to a lower value in the centre, but rapidly to a minimum near the wall. They relate this study to the effective thermal conductivity of the bed. The temperature gradients in a bed of celite cylinders have been investigated over a wide range of air velocities and bed depths by Coverly and Marshall.[34] Verschoor and Schuit[35] used a steam-heated tube packed with spheres of glass, lead, etc., and pumice and, with air and hydrogen, correlated their results in terms of the surface conductance. A similar correlation was obtained by Agarwal and Storrow[36] for similar experimental conditions extended to cover both fixed and fluidised beds. They found that surface conductances were of the same order as for plain tubes, but that end-effects due to the porous plate support had a pronounced influence. These results were in line with those of Mickley and Trilling,[37] which, as reported last year, had not been correlated satisfactorily, but which have been re-examined by Gamson[38] and a suitable basis found in terms of the surface conductance. Two papers by Boery *et al.*[39, 40] also cover the determination of film coefficients over a wide range of conditions and they show that a maximum performance is attained at a velocity approximately twice that required for the initial fluidisation.

Circulating liquids

A useful critical review of heating by means of circulating liquids has been presented by Geiringer.[41] He discusses the field of application of water, oils, organics, silicones, molten salt mixtures and metals. Considerable attention is now being given to the advantages of heat transfer by molten metals and Lyon[42, 43] has developed a new heat transfer equation applicable to the treatment of metals in turbulent flow. He



Heat exchangers in the new Esso petroleum refinery at Fawley.

obtains experimental confirmation when using a 50 wt. % K-Na alloy, an important feature being the necessity to use an alloy which wets the walls of the equipment, since transfer rates are down by half in the case of non-wetting metals. The heat transfer to liquid metals flowing between parallel walls has also been studied by Harrison for the case where only one wall is heated.[44] Of interest in this field is a paper by Seban,[45] in which he develops a treatment for calculating transfer and temperature gradients for a fluid flowing between two parallel walls at different temperatures. His method is confirmed by experimental results. At the other extreme Peck *et al.*[46] have investigated the heat transfer by natural convection between plates when separated by a gas at low pressures. They find that below 1 mm. Hg. absolute the transfer rate falls as the mean free path of the gas approaches the dimensions of the gap.

Cummings and West[47] have studied heat transfer in a kettle fitted with jacket heating and coil cooling for a wide range of solvents. The influence of added solids was also observed for the case of toluene and it was found that 25% of solids reduced the film coefficient by about 28%. Inglesent and Storrow[48] have also reported some values for the heat transfer rate from a coil to unstirred water.

Gas turbines

Further papers have appeared which arise from problems studied in connection with the development of gas turbines. Gunther[49] has examined, photographically, the mechanism of 'surface-boiling' and shown how the bubbles grow and collapse as they are swept along an electrically-heated strip. Kreith and Summerfield[50] have published further work on 'surface-boiling' using aniline and *n*-butyl alcohol as the fluids. From this work it might be expected that improved transfer rates would be obtained by adding a low boiling solvent to a non-volatile liquid which is to be heated, and Bonnet and Gerster[51] have now confirmed this by using 0 to 15% of C hydrocarbons in furfural. Using a long multi-tube steam-heated exchanger, they found that improvement in performance was proportional to the ratio of vapour to liquid leaving the heater. Progress in the work on frictioned resistance and film coefficients for air at supersonic velocities has been reported by McAdams[52] *et al.* and it is established that if turbulence is not fully developed then the film coefficient may be as low as one-tenth of that obtained under fully turbulent conditions. The temperatures in a porous plate cooled by injection of a volatile fluid and heated by hot gases (sweat cooling) have been explored by Berger.[53]

Condensation and boiling

Gloyer[54] has detailed a design procedure for condenser-coolers of the shell and tube pattern in which he used a weighted mean temperature difference. Examples are given of applications to petroleum condensers and compressor inter-stage coolers. Chu *et al.*[55] investigated the condensation of pure vapours on a single horizontal tube by varying the cooling water flow rate and extrapolating. They show that trichloroethylene and bromobenzene agree with the results expected from the Nusselt equation, but nitromethane and *n*-hexyl alcohol give a value only about half of that expected. The film coefficients for methanol and trichloroethylene condensing on inclined and vertical, plain and finned tubes have been determined by Forbes and Beatty,[56] who find that, while the coefficient per unit area is lower for the finned tubes, there is about 50% increase per unit length in the overall value. A mathematical study of the problem of dropwise condensation has been presented by Fatica and Katz.[57]

Little has appeared on the subject of boiling films, except that which can be best reviewed under evaporators. Kazakova has examined the conditions which lead to maximum heat flow in boilers at high pressures.[58]

REFERENCES

[1] E. Eckert: 'Introduction to the Transfer of Heat and Mass,' New York, 1950.
[2] D. Q. Kern: 'Process Heat Transfer,' New York, 1950.
[3] F. G. Keynes and D. J. Sandell: *Trans. Am. Soc. Mech. Engrs.*, 1950, **72**, p. 767.
[4] A. L. Lindsay and L. A. Bromley: *Ind. Eng. Chem.*, 1950, **42**, p. 1508.
[5] L. Riedel: *Chemi-Ingr. Technik.*, 1950, **22**, p. 54.
[6] K. A. Beatty, A. A. Armstrong and E. M. Schoenborn: *Ind. Eng. Chem.*, 1950, **42**, p. 1527.
[7] H. S. Hatfield and F. J. Wilkins: *J. Sc. Instruments*, 1950, **27**, p. 1.
[8] M. Laznovsky: *Paliva*, 1950, **30**, p. 27.
[9] J. J. Broeze, G. Ribaud and O. A. Saunders: *Chaleur et Industrie*, 1951, **32**, p. 3.
[10] J. E. de Graaf and M. W. Thring: *Ibid.*, 1951, **32**, p. 5.

[11]F. M. Comerford: *Ibid.*, 1951, **32**, p. 31.
[12]F. W. Jensen and K. Anderson: *Ind. Eng. Chem.*, 1951, **43**, p. 176.
[13]S. S. Penner: *J. Appl. Phys.*, 1950, **21**, p. 685.
[14]H. C. Hottel: 'Nuclear Energy Power for Aircraft,' Heat Transfer Lecture II, 1949, p. 76.
[15]C. A. Landferrmann: *Chem.-Ing.-Teck.*, 1950, **22**, p. 5.
[16]T. K. Sherwood: *Ind. Eng. Chem.*, 1950, **42**, p. 2077.
[17]R. G. Deissler: *Trans. Amer. Soc. Mech. Engrs.*, 1951, **73**, p. 101.
[18]P. V. Danckwerts: *Trans. Faraday Soc.*, 1950, **46**, p. 701.
[19]T. Tinker: 'Nuclear Energy Power for Aircraft,' Heat Transfer Lecture II, 1949, p. 293.
[20]O. P. Bergelin, G. A. Brown, H. L. Hull and F. W. Sullivan: *Trans. Am. Soc. Mech. Engrs.*, 1950, **72**, p. 881.
[21]F. D. Cardwell: *Ibid.*, 1950, **72**, p. 1061.
[22]S. A. Rapoport: *Zhur. Teck. Fiziki.*, 1950, **20**, p. 1121.
[23]R. Sohngen: *Chem.-Ing.-Teck.*, 1951, **23**, p. 81.
[24]W. M. Kays and A. L. London: *Trans. Amer. Soc. Mech. Engrs.*, 1950, **72**, p. 1075, 1950, **72**, p. 1087.
[25]D. Aronson: *Ibid.*, 1950, **72**, p. 967.
[26]C. Simpelaar and D. Aronson: *Ibid.*, 1950, **72**, p. 955.
[27]H. O. McMahon, R. J. Bowen and G. A. Bleyle: *Trans. Amer. Soc. Mech. Engrs.*, 1950, **72**, p. 623.
[28]J. G. Knudsen and D. L. Katz: *Chem. Eng. Progr.*, 1950, **46**, p. 490.
[29]G. W. Billman, D. M. Mason and B. H. Sage: *Ibid.*, 1950, **46**, p. 625.
[30]M. Leva: *Ind. Eng. Chem.*, 1950, **42**, p. 498.
[31]E. Singer and R. H. Wilhelm: *Chem. Eng. Progr.*, 1950, **46**, p. 343.
[32]W. D. Munro and N. R. Amundson: *Ind. Eng. Chem.*, 1950, **42**, p. 1481.
[33]M. Morales, C. W. Spinn and J. M. Smith: *Ibid.*, 1951, **43**, p. 225.
[34]C. A. Coverly and W. R. Marshall: *Chem. Eng. Progr.*, 1951, **47**, p. 141.
[35]H. Verschoor and G. C. A. Schuit: *Appl. sci. Res.*, 1950, **A2**, p. 97.
[36]O. P. Agarwal and J. A. Storrow: *Chem. & Ind.*, 1951, **17**, p. 321.
[37]H. S. Mickley and C. A. Trilling: *Ind. Eng. Chem.*, 1949, **41**, p. 1135.
[38]B.W. Gamson: *Chem. Eng. Progr.*, 1951, **47**, p. 19.
[39]A. Boery and P. E. Gishler: *Chem. Canad.*, 1949, **1**, p. 35.
[40]A. Boery, J. Klassen and P. E. Gishler: *Can. J. Research*, 1950, **28F**, p. 287.
[41]P. L. Geiringer: *Chem. Engg.*, 1950, **57**, p. 136.
[42]R. N. Lyon: *Chem. Eng. Progr.*, 1951, **47**, p. 75.
[43]*Idem.: Microfilm Abstr.*, 1950, **9** (3), p. 27.
[44]W. B. Harrison: *Trans. Am. Soc. Mech. Engrs.*, 1949, **71**, p. 797.
[45]R. A. Seban: *Ibid.*, 1950, **72**, p. 789.
[46]R. E. Peck, W. S. Fagan and P. P. Werlein: *Ibid.*, 1951, **73**, p. 281.
[47]G. H. Cummings and A. S. West: *Ind. Eng. Chem.*, 1950, **42**, p. 2303.
[48]H. Inglesent and J. A. Storrow: *Ind. Chem.*, 1950, **26**, p. 313.
[49]F. C. Gunther: *Trans. Am. Soc. Mech. Engrs.*, 1951, **73**, p. 115.
[50]F. Kreith and M. Summerfield: *Ibid.*, 1950, **72**, p. 869.
[51]W. E. Bonnet and J. A. Gerster: *Chem. Eng. Prog.*, 1951, **47**, p. 151.
[52]J. Kaye, J. H. Keenan and W. H. McAdams: *Trans. Am. Soc. Mech. Engrs.*, 1951, **73**, p. 267.
[53]J. Berger: *C.R. Acad. Sci. Paris*, 1950, **230**, p. 1935.
[54]W. Gloyer: *Ind. Eng. Chem.*, 1950, **42**, p. 1361.
[55]J. C. Chu, M. Dmytryszyn, W. Tichy, K. C. Kubik and O. L. Smith: *J. Appl. Chem.*, 1951, **1**, p. 73.
[56]A. V. Forbes and K. O. Beatty: *Chem. Eng. Progr.*, 1950, **46**, p. 531.
[57]N. Fatica and D. L. Katz: *Ibid.*, 1949, **45**, p. 661.
[58]E. A. Kazakova: *Izvest. akad. nauk. SSSR.*, 1950, **9**, p. 1377.

Corrosion Processes and their Prevention

STATISTICS show the enormous importance of metallic corrosion in world economics at the present time, and there is much evidence of a growing recognition of its importance on the part of industry. Neglect of the subject at the academic level has perhaps been due to the name of 'corrosion,' with its suggestion to many of a complete absence of aesthetic interest and a claim to investigation based only on economic necessity. The object of a lecture by Dr. W. H. J. Vernon at a recent meeting of the Royal Institute of Chemistry was primarily to emphasise that corrosion, covering as it does the whole range of reactions between metals and their non-metallic environments, presents, in fact, a field of the utmost attractiveness for study and research.

The conception of corrosion as a reversion, or partial reversion, from the metastable condition of the metal to the stable condition of the mineral is now generally recognised. As to the nature of the processes involved in this reversion, the story is complex and fascinating. Certainly no less than in any other branch of science, and in contradistinction to the popular view, one is impressed by the order and regularity that one finds. The study of corrosion processes breaks into a number of cognate fields, *e.g.* chemistry and physics, metallurgy and engineering, mineralogy and microbiology, but probably the best general preparation for such study is that afforded by the training of the physical chemist. Corrosion not only provides a fruitful ground for research, both of the fundamental and *ad hoc* type; it has the added incentive, in either case, of contributing to an ultimate object of national importance, the conservation of metallic resources.

Corrosion reactions

Corrosion reactions may be divided broadly into two groups—'metal-liquid (electrolytic) reactions' and 'metal-gas reactions.' Processes that fall definitely within the first category are those of immersed and underground corrosion. Metal-gas reactions are represented typically by direct oxidation at ordinary and elevated temperatures and by certain tarnishing processes at ordinary temperatures. Atmospheric corrosion occupies an intermediate position, since both metal-liquid and metal-gas reactions enter into the process, which is pre-eminently the resultant of film formation and film breakdown. None of these divisions must be regarded as being rigid or exclusive.

Many interesting details and examples of various aspects of corrosion were given before the lecture was concluded by reference to two methods of corrosion prevention which depend entirely upon the control of the corrosion mechanism, *viz.* corrosion inhibitors and cathodic protection.

Discussion

Dr. Herd opened the discussion with a question on sodium benzoate inhibitor, which the lecturer said forms a film and acts as an anodic but 'safe' inhibitor. In answer to Mr. C. Hollingsworth, Dr. Vernon said that the addition of either chromate or benzoate to water, in concentration sufficient to prevent attack on steel during immersion, afforded very limited protection on subsequent exposure to air, contact with the solution containing the inhibitor being necessary for maintenance of the film.

Messrs. E. Simpson and T. McLachlan asked questions about the effect of impurities in metals both from the viewpoint of inhibition of the electrolytic process by extreme purity and from the converse effect, *viz.* alloying with elements capable of producing protective films, as in the production of stainless steels by addition of chromium and nickel to the metal; most progress had been made by the second approach. In reply to Mr. C. H. Upfold, the lecturer referred briefly to the mechanism of corrosion fatigue, but added that a series of lectures would be required to deal with the subject. The final question came from Mr. A. Pickles, who asked if it is possible for desulphurican microorganisms, which may thrive on organic fibres in a protective wrapping, to penetrate a non-aqueous system. Dr. Vernon confirmed that the organisms do make use of the decomposition products of organic matter, so that organic fibre wrappings should be avoided. A good bituminous coating with inorganic reinforcement or filling is the best that can be advised, and there is no evidence that the bacteria can penetrate such material.

Handling ethylene oxide. A colourless gas at ordinary temperatures and pressures, ethylene oxide is inflammable, chemically very reactive, mildly toxic and its vapour forms explosive mixtures with air. These properties necessitate the use of certain precautions when handling and or storing. These precautions are detailed in a booklet *The Handling and Storage of Ethylene Oxide*, recently published by Petrochemicals Ltd. Provided these are strictly adhered to, ethylene oxide can be used with complete safety. The contents include sections on the physical properties, inflammability and explosibility, toxicity, chemical reactivity, reaction vessels and equipment, storage of ethylene oxide, delivery and containers, rail tank cars and road tankers, regulations in force governing use and transport, detection of small quantities of air and the taking of samples.

Handling Acetylene under Pressure in Chemical Reactions

By S. A. Miller, M.A., B.Sc., Ph.D.

(*The British Oxygen Co. Ltd.*)

When at the close of the war German chemical industry was investigated, one of the few features that created a deep impression was the discovery that chemical processes had been operated using acetylene at high pressures. The steps which the Germans took to enable them to handle with impunity compressed acetylene for chemical purposes were based on three principles: (1) Elimination of factors known to initiate decomposition; (2) Adoption of methods whereby the violence of decompositions is reduced when they do occur; (3) Use of plant which would withstand the force of decompositions of reduced violence. The German claims are critically examined in this article.*

Initiation

ACETYLENE decompositions have been stated to be initiated by heat, catalysts, chemical reagents, and external detonations. In the course of our own investigations we are coming to the conclusion that the initiation of acetylene decomposition is always due to the presence of a region of high temperature. Such a region of high temperature need only be small in extent, perhaps smaller than of the order of a cubic millimetre. The temperature needed to initiate acetylene decomposition varies somewhat with pressure. Recent American work suggests that a temperature of 635°C. is needed to initiate decomposition in acetylene at atmospheric pressure, and 540°C. at 1 atmg. We have found that violent decompositions of acetylene occur in tubes heated to 475°C. into which acetylene is admitted at any pressure from 2 to 10 atmg. At lower temperatures, down to 300°C., the acetylene reacts to form condensation products, consisting of oily and tarry matter, but no free carbon. Such condensation is highly exothermic, and under certain circumstances initiation of the more violent so-called decomposition can follow. Thus the admission of acetylene at 10 atmg. into a tube at 350°C. containing small amounts of activated carbon or metallic oxides will result in decomposition similar to that observed in the same tube at 475°C. in the absence of such solids. It is suggested that the condensation reactions occur on the surface and raise the temperature locally to above 475°C., which is sufficient to initiate a decomposition wave passing through the bulk of the gas. These observations may help in explaining the recorded cases of catalytically initiated acetylene decomposition.

The above observations apply to pressures up to 10 atmg. At 20 atmg. explosive decomposition occurs even in the absence of solid surfaces at 350°C., but not at 330°C.

So-called chemical initiation also appears to be a localised exothermic reaction resulting in a local hot spot sufficient to initiate general decomposition. The German observation that solid caustic potash at 160°C. can initiate acetylene decomposition, an observation which we have ourselves confirmed (at any rate, of 200°C.), appears to come within this category.

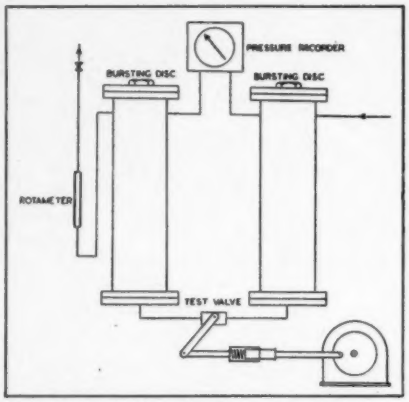


Fig. 1. Equipment for valve testing.

Initiation of acetylene decomposition by means of copper acetylide is also due to the localised high temperature, which can be produced by the decomposition of a fragment of this material.

Precautions against initiation

The precautions which the Germans are reported to have taken to avoid initiation include the use of their so-called explosion-proof electric motors, starters and lighting fittings; it must be noted at once that such fittings do not meet British flame-proof requirements for Group II gases and vapours, and that there are no British standards for electrical gear suitable for working with Group IV gases, which include acetylene. Other precautions to avoid initiation are reported to include the use of water lubrication in the acetylene compressors, the use of corrosion-resistant steel (so as to avoid internal friction by movement of corrosion products), the avoidance of metal-to-metal seatings in valves, and avoidance of hot spots in catalyst beds by the use of a high rate of liquid flow, together with efficient distribution over the catalyst.

What is not made clear in the many reviews is the fact that the above precautions were made to apply to one process only, *viz.*, the production of butynediol from acetylene and formaldehyde. In this process, operated on a very large scale at an acetylene pressure of 6 atmospheres, the catalyst consists of supported copper and bismuth acetylides. The Germans operated a number of other high-pressure acetylene processes, including the preparation of vinyl ethers, koresin (condensation product of acetylene and tertiary butyl phenol, a tackifier for Buna synthetic rubber), vinylpyrrolidone (the monomer of a blood plasma substitute), vinylcarbazole (polyvinylcarbazole being valuable in the electrical field as a mica substitute), and, on a laboratory scale, cyclooctatetraene. All these processes operated at appreciably higher pressures of acetylene than the butynediol process and in none of them is there record of any special precaution taken to avoid initiation, other than the protection of electrical equipment in a way which would be considered to be totally inadequate in this country.

Valves

The reference to the avoidance of valves with metal-to-metal seatings, and also of spring-loaded non-return valves, implies that acetylene decomposition could be initiated in using such valves, and there is no available record of any direct evidence in support of this. It might be considered that this danger could only apply in the case of valves in wide pipelines, since this type of valve is in normal use in narrow bore lines in acetylene-compressing stations and, indeed, in acetylene cylinders throughout the world. The other possibility is that this precaution, which is only mentioned in regard to the butynediol plant, is necessary in that process because of the hazard due to lodgment of material contaminated with copper acetylide on the valve seats. We have taken an ordinary ¼-in. steel valve, where the seal is formed

*Read before the Jubilee Meeting of the British Acetylene Association and published by permission.

by screwing metal to metal, and arranged for it to be opened and shut automatically at the rate of one operation a minute, with acetylene at 12 atm. passing through it. The arrangement is shown diagrammatically in Fig. 1.

In 20,000 such operations there was no sign of acetylene decomposition. The process was repeated after introducing rust and grit into the valve. Again there was no response to 20,000 operations. Finally, some highly sensitive copper acetylide was prepared in the laboratory and mixed with charcoal; simply tapping the mixture resulted in minute but clearly visible sparks. This mixture was introduced at the seating of the valve, and once again it was opened and shut 20,000 times without initiating any decomposition in acetylene at 12 atm. It is considered that hot spots produced in this way, in very close proximity to a large mass of metal, are incapable of initiating decomposition in acetylene.

Copper acetylide

In general, while it is dangerous to allow copper to remain in contact with acetylene at high pressure, the mere presence of copper or copper salts does not automatically initiate acetylene decomposition; the butynediol process actually operated with copper acetylide as catalyst. The sensitivity of copper acetylide itself is very much a function of the manner in which it is produced. We have prepared specimens of copper acetylide and then placed a few milligrams of the material on a small anvil inside a tube containing acetylene at 2 atmg. and arranged for a $\frac{1}{4}$-in. steel ball to drop on the anvil from a height of 30 in.; the ball was held in position by means of electromagnet while the acetylene was fed into the cylinder. The fall of the ball was sufficient to cause an explosion of all the acetylene in the tube. On the other hand, when a brass or copper anvil was used and a film of acetylide formed on it, it was not found possible to decompose the film in a way to initiate the decomposition of acetylene, although several attempts were made to form particularly sensitive films.

Tube bundles

In regard to limitation of the violence of decomposition, the published accounts lay great emphasis on the packing of wide pipes with bundles of narrow tubes and the packing of rings of dead spaces in the plant. These were measures which were taken in view of the observations made by I.G. investigators that the peak pressure attained in a decomposition wave through acetylene is appreciably lower in narrow tubes than in wider tubes. Once again it must be noted that the use of tube bundles appears to have been confined to the butynediol plant, possibly because the scale of operation in the other cases was not large enough to demand the use of wide-bore pipes for carrying acetylene under pressure.

The available evidence on the efficacy of tube bundles is neither extensive nor convincing. The Germans measured the peak pressures reached in explosions in tubes of various diameters by the size of the impression formed when a steel ball is driven into a copper block by the force of the explosion. To some extent this system was compared with measurements made with a quartz Piezo crystal element coupled to a cathode-ray oscillograph. It was found that the impression method gave figures of some accuracy for pressures up to 100 atmg., but was thereafter increasingly inaccurate, the inaccuracy being up to 100% or more above 200 atmg. Experiments were carried out in pipes of up to 16 in. diameter packed throughout their length with bundles of $\frac{1}{2}$ in. bore thin wall steel tubes. In experiments at up to 6 atmg. initial pressure, a variety of figures are recorded for the maximum pressure obtained, from which it is deduced that under these conditions the pressure reached is 'high but not intolerable.' Nevertheless, one experiment records a maximum pressure of 400 atmg. in a 4-in. tube packed with tube bundles.

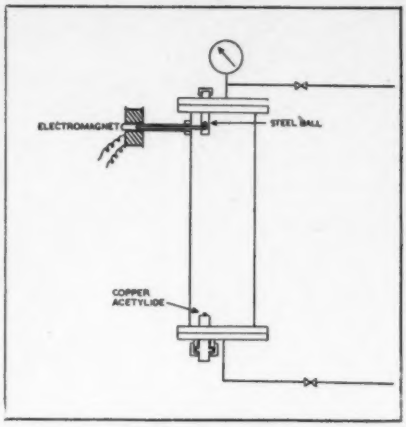


Fig. 2. Initiation by copper acetylide.

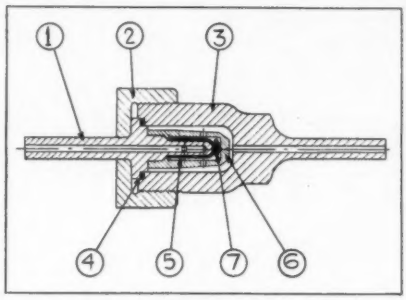


Fig. 3. Magin non-return valve.

Part No.	Description	Mat.
1	Up-stream body	M.S.
2	Body cap	M.S.
3	Down-stream body	M.S.
4	Joint ring	
5	Rubber sleeve	
6	Sheath	M.S.
7	Washer	M.S.

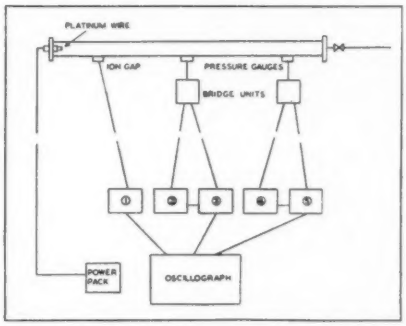


Fig. 4. Equipment for measuring explosion pressure and velocity: (1) Trigger circuit and time marker; (2) oscillator; (3) amplifier; (4) oscillator; (5) amplifier.

Non-return valve

Records of the German work also refer to the danger of using the normal type of non-return valves in pipelines containing acetylene under pressure, and describe a non-return valve specially developed by an engineer named Magin which would be safe under these conditions. The Magin valve is essentially an enlarged form of the valve used in bicycle tyres, consisting of a rubber sleeve over small holes. When acetylene is passing in the forward direction the pressure keeps the valve open, but if there is a decomposition the rubber is supposed to close over the hole at a quicker rate than the decomposition wave strikes back. We have prepared specimens of Magin valve, which were examined for us by Mr. J. S. Skelton, of the Home Office. Apart from finding that the flow characteristics were far from satisfactory, he reported that the rubber failed when a decomposition wave struck it, and we consider that any valve based on this principle would be quite valueless in acetylene pipelines.

In effect, the only precaution which appears to have been fairly generally observed in the compressed acetylene processes other than the butynediol plant was the dilution of acetylene with nitrogen. Even so, there appears to have been operated at Oppau a batch process for vinylating isobutanol at 25 to 28 atm. using undiluted acetylene.

Conclusions

There are several other statements in the report on this work for which the evidence presented is quite insufficient to justify the conclusions specified, so that either the full extent of the investigations carried out has not been made available, or a re-examination of methods by which the violence of acetylene decomposition can be controlled is still needed. We have recently begun experimental investigations with such an aim in view. The maximum pressure is being measured by the change in capacity of a condenser coupled up to a cathode-ray oscillograph. An explosion wave is initiated in acetylene by the fusion of a platinum wire; it then passes a trigger circuit and two condenser elements at a fixed distance apart. The oscillograph trace is recorded for a few milliseconds for each condenser circuit on a strip of photographic film. The

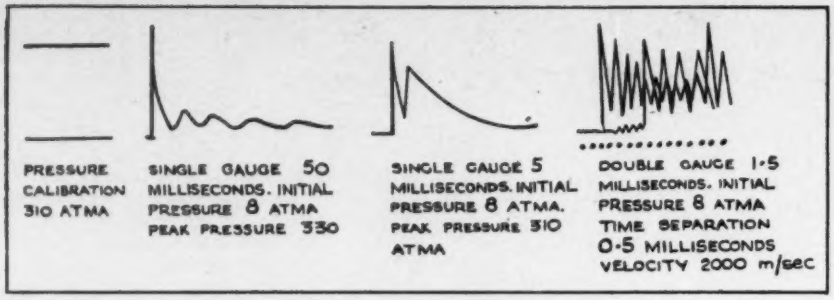

PRESSURE CALIBRATION 310 ATMA
SINGLE GAUGE 50 MILLISECONDS. INITIAL PRESSURE 8 ATMA PEAK PRESSURE 330
SINGLE GAUGE 5 MILLISECONDS. INITIAL PRESSURE 8 ATMA. PEAK PRESSURE 310 ATMA
DOUBLE GAUGE 1·5 MILLISECONDS. INITIAL PRESSURE 8 ATMA TIME SEPARATION 0·5 MILLISECONDS VELOCITY 2000 m/sec

Fig. 5. Explosion records.

double trace as obtained contains two peaks, the height of the peaks being a function of the maximum pressure, and the horizontal distance between the peaks being a function of the time taken for the explosion wave to pass through the fixed distance between the two condenser elements.

The performance of the system was first checked with mixtures of hydrogen and oxygen at atmospheric pressure, and the peak explosion pressure found to be about 18 atma., in agreement with published work. The trigger circuit depends on the presence of ions in the explosion wave front; it was found that the explosion front in the case of acetylene was incapable of actuating the ion gap, presumably indicating an insufficiency of ions. This difficulty was overcome by coating the terminals of the ion gap with a thin film of collodion, which decomposed in the explosion wave front and provided the necessary ions for actuating the trigger circuit.

Experiments in 1-in. tubes have shown the decomposition of acetylene at 4.4 atma., producing a peak pressure of 110 atm., and proceeding at a velocity of 800 metres/sec. These are not detonation conditions, in spite of the fact that the explosion was propagated along 15 ft. of straight tube before its velocity was measured. But the peak pressure after an initial pressure of 7.8 atma. was 310 atm., and the velocity about 2,000 metres/sec. Experiments with wider tubes and still longer lengths are to be carried out, and since detonation conditions are indeed reached the efficacy of tube bundles and other packing devices to prevent detonation is to be examined.

It has already been noted that the only general measure adopted in German plant was dilution of the acetylene with nitrogen. Here, again, the published German data do not appear to give a solid basis for the practical conditions which were actually put into operation. Thus the safe percentage of acetylene in admixture with nitrogen at a total pressure of 5 atm. at 100° was said to be 50%, and at 20 atm. 30%. In a vinyl ether plant operating at 5 atm. 90% acetylene was used and operating at 20 atm. 55% acetylene. Further, the margin between a fairly severe explosion and no decomposition at all is narrow.

Thus a mixture containing 49% of nitrogen at 5 atm. was said not to explode, but

EFFECT OF NITROGEN ON THE DECOMPOSITION OF ACETYLENE AT 5 ATMG.

Nitrogen in mixture %	*Peak pressure atmg.*
0	62
10	61
20	58
30	53
47	49
48	43
49	no decomposition

one containing 48% of nitrogen was said to give a peak pressure of 43 atm. and one with no nitrogen gave a pressure of 62 atm.

Since the war American data have been published concerning the amounts of various diluents necessary to prevent explosion of acetylene at pressures up to 7 atm. This does not cover the effect of lesser dilution on the severity of explosion when it does occur, but it does show that there are more valuable diluents than nitrogen, in particular the lower hydrocarbons, such as propane or butane.

It will be seen that, although the Germans undoubtedly were able to operate plants with compressed acetylene under conditions which in years gone by would have been considered impossible to maintain because of the certainty of ultimate disaster, the common impression that they provided all the necessary data from which conditions for safe operation can be predicted is not quite correct. The main positive precaution is the avoidance of all possible sources of initiation, and this is believed to mean the prevention of any hot spots, *i.e.* minute volumes raised to temperatures above 500°C., or possibly even 350°C.

The author wishes to thank Dr. D. V. N. Hardy, Mr. E. Penny and Mr. A. Please for assistance in preparing this paper, and the Directors of the British Oxygen Co. Ltd. for permission to publish.

X-ray Analysis of Petrol

A rapid and efficient new *x*-ray technique which speeds production of petrol and motor oil of uniform quality was described at a recent conference on analytical and applied spectroscopy, sponsored by the American Chemical Society and the Spectroscopy Society of Pittsburgh. The new method can be used to determine the quantity of anti-knock agent in petrol or the amount of sulphur contamination in lubricating oil, according to a report by Dr. Samuel W. Levine and Dr. A. H. Okamoto, Atlantic Refining Co.

Employing a Geiger counter and a commercial high-intensity *x*-ray generator, the new technique is faster than previous procedures and can detect a difference of 0.0007 oz. of tetraethyl lead anti-knock per gal. of petrol, or 0.02% of sulphur in lubricating oil or crude oil, the report said. Most petrols now contain tetraethyl lead, and the precise control of the quantity present is important from both the quality and the economy standpoints.

Since the absorption of *x*-rays is an atomic property, the chemical combination or physical environment of the atom will not affect the results. Irradiation of a sample by *x*-rays does not change the nature of the sample and it may therefore be used again for some other purpose. Because of the availability of high-intensity *x*-ray generating and high-efficiency detecting equipment, measurements may be made in a short time as compared to chemical methods. Since the procedure is simple, the analysis may be carried out by a routine operator.

Laminated Plastics

In this comprehensive review* of a section of the plastics industry the processes of laminating and the properties and applications of laminates are carefully described.

The earlier chapters deal with the processes of resin impregnation, laminating and post-forming and with the plant and equipment necessary for these operations. Subsequent chapters are devoted to individual resins and groups of resins, while the concluding portion is concerned with the widespread applications of these versatile materials.

Among several appendices, those listing laminates commercially supplied both in this country and Germany are particularly valuable and, in addition to the references that follow each chapter, another appendix includes references up to 1947 for further study.

The book is very well illustrated and the photographs are among its most attractive features.

There are certain minor errors in chemical formulae, but these do not detract materially from a work which, particularly for the non-specialist, covers adequately a field of plastics technology which is becoming of progressively increasing importance. It can be recommended both to users of laminates and to students as a reference work covering the basic facts of laminating and related processes.

J.H.M.

**Laminated Plastics*, by G. S. Learmonth, Ph.D., F.R.I.C. Leonard Hill Ltd., London. Pp. 270. 112 illustrations. 25s. 10d. post free.

Acetylene Manufacture and Utilisation in Germany

The position of acetylene in the war-time economy of Germany and the advances made in that country in the chemistry of acetylene have been surveyed in a recent review* based largely upon the information obtained by Allied investigators after the war. Below we give abstracts from this review, which should be read in conjunction with Mr. Miller's article appearing in this issue.

Acetylene from carbide

A LARGE variety of generators was used in Germany, with four main types:

(*a*) Carbide-to-water generators;
(*b*) Water-to-carbide generators;
(*c*) Water recession generators, somewhat on the Kipp principle; and
(*d*) Dry generators.

Of these the last-mentioned type were the most modern and in most general use.

These generators were so-called because the carbide and water were mixed in such proportions as to maintain the reaction temperature at about 70° C. and to produce acetylene and a dry lime (water 5 to 8%) residue. Owing to the shortage of lime this residue was heated and partly used again for the manufacture of carbide, after blending with further stocks of raw lime, and partly used for agricultural purposes. There were two types of this generating plant, a large vertical type in use at Burghausen (Wacker) and a horizontal rotary type, in use at Ludwigshafen and Gendorf (I.G. Farbenindustrie), inside which was a rotary screen onto which the calcium carbide was fed. Of these, the former appeared to have advantages over the latter with regard to simplicity of construction and operating cost and length of operating time. A plant similar to the vertical type, which operated with carbide dust, was in use at Knapsack.

Carbide production and allocation

The carbide factories, which were located near power plants, used current produced from cheap brown coal and the price of carbide was thus relatively low, *e.g.* cyanamide could compete in price with ammonium sulphate. Such conditions cannot be reproduced at present in the U.K. and time will tell whether the installation of the projected hydroelectric power plants will permit of the production of carbide at a competitive price. Power consumption was given as 3,300 kWh/ton of carbide and, taking in conjunction the yield of acetylene from carbide, 83 to 96 l. of acetylene were obtained per kWh.

Acetylene by electric arc

The Chemische Werke Hüls is described as the first successful producer of acetylene by electrothermal cracking of hydrocarbons. As far as can be seen from a study of the reports on Germany, Hüls seems to be the only producer of acetylene by arc.

ALLOCATION OF CARBIDE FOR VARIOUS USES

Product use	*Quantities in mid-1942 tons/month*	%	*Ultimate quantities planned tons/month*	%
Cyanamide	26,000	23.65	58,000	27.60
Buna	23,000	20.90	42,000	20.00
Vinyl products and chlorinated hydrocarbons	6,000	5.45	12,500	6.00
Manufacture of ethylene for ethylene oxide	5,000	4.55	18,000	8.60
Acetaldehyde (not for buna)	23,000	20.90	28,000	13.30
Aldehyde spirits	—	—	7,000	3.30
Miscellaneous chemicals (acrylonitrile, etc.)	—	—	4,500	2.15
Lubricants	—	—	4,500	2.15
Carbon black	2,000	1.80	3,500	1.65
Welding and cutting purposes	20,000	18.20	27,000	12.85
Miscellaneous (calcium silicide, export, etc.)	5,000	4.55	5,000	2.40
	110,000	100	210,000	100

There seems to be general agreement that the plant was designed to operate on gas from the coal hydrogenation plant, and when this was cut off by bombing, natural gas was used.

The total production is given as 200 tons/day of 97% acetylene, with a power consumption of 9.5 to 10.5 kWh/kg. of pure acetylene, and compares favourably with power requirements by the carbide route.

Acetylene by partial oxidation of hydrocarbons

The plant at Oppau produced dilute acetylene by the partial oxidation of 4,000 m³/hr. of methane in five burners, each taking 800 m.³/hr. The plant had worked satisfactorily for some years.

Acetylene by thermal cracking of hydrocarbons

A small-scale plant for the thermal cracking of methane was developed at Ruhrchemie, Holten, and it is stated that a full-scale plant was designed in 1943 for the Hungarian firm of Nitrochemie A.G. The plant was to produce 7,000 kg./day of acetylene and the power consumption was estimated to be 1,077 kWh.

Handling of acetylene

I.G. Farbenindustrie had carried out investigations on the conditions under which acetylene would decompose and the consequent pressures developed. Decomposition was studied as a function of pressure, temperature, vessel size, moisture content, type of igniter and quantity and kind of diluent gases.

It was found that the gas could be compressed up to 15 to 20 atm. in slow-moving reciprocating compressors by stages with proper cooling.

In 1940 the same company had the idea of piping acetylene for a distance of 83 km., and experimental work was carried out at Griesheim. It was found that in long pipes of wide diameter, detonation occurs at low pressures, *e.g.* 1.4 kg./cm.², with resulting pressures of several hundred atm. Small percentages of nitrogen up to 25% had no beneficial effect, but with 50% nitrogen there was a small pressure range free from detonation. It was considered that a pressure of not more than 0.3 kg./cm.² could be used in long pipes of large diameter or 3.0 kg./cm.² for 1:1 nitrogen-acetylene mixtures.

A brief summary of the recommended practice in German plants is given below.

All equipment, including valves and piping, was designed to withstand at least ten times the normal operating pressure of acetylene, or the partial pressure of acetylene if a diluent was being used. Non-return valves and flame arresters were interposed in long pipelines. No copper or copper alloys were employed in the manufacture of plant, including compressors, in which acetylene was to be used. All the pipelines were as short and as narrow as possible; where it was essential to use piping of more than 35 mm. diameter this was filled with a number of smaller tubes in the manner of a honeycomb, which broke up the large volume of gas into a number of smaller volumes as well as increasing the overall thermal conductivity of the gas space. Furthermore,

* 'The Acetylene Industry and Acetylene Chemistry in Germany during the Period 1939-45,' by R. Owens, Ph.D., and A. W. Johnson, Ph.D., A.R.C.S. Published by H.M.S.O. for D.S.I.R., price 3s. 6d. (America, 90 cents), by post 3s. 9d.

effective explosion arresters could be made by packing lengths of pipe with Raschig rings and thus various pieces of equipment could be isolated. There are three types of decomposition of acetylene: (1) a slow decomposition in a time of the order of 1 sec. or longer in which it is possible to arrest the decomposition; (2) an 'explosion' which has a speed of propagation of about 1,000 m./sec., in which the pressure is increased about 20-fold; and (3) a 'detonation' with a speed of propagation of about 10,000 m./sec. and in which the pressure is increased about 100-fold and almost invariably causes disruption of the vessel. The nature of the explosion depends on many factors, *e.g.* the size and shape of the vessel, the temperature, pressure and composition of the gas. The explosion limits of acetylene and acetylene mixtures had been calculated and were of prime importance in planning new experiments and processes, although the possibility of an explosion initiator being present had not been overlooked, *e.g.* diacetylene in the Hüls arc acetylene. The presence of water or other liquids was also a desirable feature in many of the acetylene pressure reactions as it decreased the chances of initial ignition as well as dissipating the heat from any local hot-spots.

In the cylinder filling plants the acetylene was delivered at 30 atm. and the lines were 10 mm. o.d. by 8 mm. i.d. seamless steel tubing.

Solid and liquid acetylene

In 1931 the I.G. Farbenindustrie obtained a German patent for the production of acetylene 'snow' similar to carbon dioxide 'snow.' This solid acetylene was found to be relatively insensitive to shock. It burns quietly with the formation of soot. The solid was obtained by condensing gaseous acetylene on a cylinder cooled with liquid air.

The work on liquid acetylene was carried out with a view to examining the possibility of transporting liquid acetylene at atmospheric pressure. It was prepared by allowing the solid to melt, and it was considered, after much experimentation, that the addition of 7 to 9% carbon dioxide was sufficient to stabilise the liquid.

The use of acetylene in chemical processes

In this summary from the report, in general only those products available from the direct utilisation of acetylene have been considered. It must be remembered that in many cases the products are intermediates only and that their relevant importance needs to be assessed in the light of the final product involved.

Acetaldehyde

The main product from acetylene was acetaldehyde by the hydration of acetylene. The old process was a discontinuous batch process using as catalyst a liquid mass of mercuric sulphate in sulphuric acid. The mercuric sulphate is reduced to mercurous sulphate and finally to metallic mercury during the course of the reaction, and the expended catalyst has to be withdrawn periodically and re-oxidised to the mercuric state.

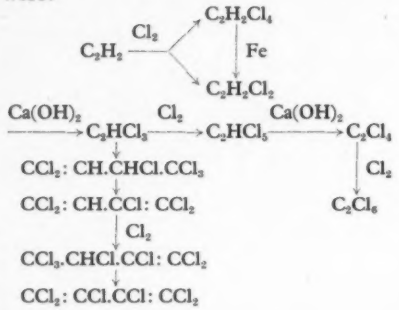
The process was apparently only worked at Burghausen, and was modified elsewhere by the addition of ferric sulphate to the catalyst, whereby the mercury salt was oxidised at the expense of the iron salt. This enabled a continuous process to be developed in which the catalyst solution was continuously removed from the system and returned after oxidation by nitric acid or air.

Chlorinated compounds

Tetrachlorethane was produced by the liquid phase chlorination of acetylene, using iron filings as catalyst. The old process was carried out in a lead-lined agitated jacketed vessel. Chlorine and acetylene were passed into a batch of tetrachlorethane at 70 to 90°C., and the product overflowed continuously into boiling milk of lime which converted the tetrachlorethane to trichlorethylene. Boiling the tetrachlorethane with iron scrap gave the isomers of dichlorethylene.

In the new process a similar vessel was used, but a vacuum pump and condenser were attached and the tetrachlorethane distilled off. The heat of reaction was removed as latent heat in the tetrachlorethane vapour and the temperature controlled by varying the pressure.

The chemical reactions involved in the formation of this group of compounds were:



Vinyl chloride

This important monomer was prepared by the direct addition of hydrochloric acid to acetylene.

Vinyl acetate

This ester was prepared by passing acetylene and acetic acid vapours at 170 to 200°C. through charcoal impregnated with zinc acetate. It was the most important vinyl ester and was produced at the rate of 15,000 tons p.a.

Vinyl acetylene

This intermediate for neoprene was prepared by passing acetylene through a reactor containing an acidified solution of ammonium and cuprous chlorides at 60°C.

Acrylonitrile

This monomer was prepared by the direct combination of acetylene and hydrogen cyanide. The catalyst employed was a solution containing cuprous sodium and potassium chlorides. The pressure was approximately atmosphere and the temperature 70 to 90°C.

Butadiene synthesis and intermediates

The main large-scale use of the ideas developed by Reppe was in the production of butadiene through 1:4-butinediol, at the rate of approximately 1,500 tons/month.

The first stage in the synthesis was the interaction of formaldehyde and acetylene at 4.5 atm. 100 to 120°C. and using copper acetylide as catalyst.

$$CH_2O + HC{\equiv}CH + CH_2O \longrightarrow CH_2OH{-}C{\equiv}C{-}CH_2OH$$

The next stage was the hydrogenation of this compound to butanediol at 300 atm., 120°C., by means of a copper-nickel catalyst. The final stage was dehydration to butadiene at 1 atm., 280°C., with sodium-phosphate catalyst.

It will be seen that this route requires only half the amount of acetylene required in the acetaldehyde route and the various reasons given for the adoption of this route by the Germans include:

(1) To utilise methanol available from Leuna.
(2) To avoid the necessity for additional carbide capacity.
(3) To avoid the use of mercury and the consequent unavoidable expenditure of this catalyst.
(4) To have available in butinediol, a versatile raw material which could be used for the production of other products, *e.g.* adipic acid, hexamethylenediamine, etc. Reppe, the leading German acetylene chemist, seems to have wanted to get away from benzene as a starting point for polyamides and even for styrene.

Vinyl ethers

The vinyl ethers were prepared in Germany by the reaction of acetylene and alcohols under pressure and in the presence of a catalyst comprising the alkali metals, the alkaline-earth metals, their hydroxides, alcoholates, phenates or cyanides, as well as zinc and cadmium salts of organic salts.

The alcohol must be in the liquid phase; if the boiling point of the alcohol is less than the reaction temperature then pressure must be applied, *e.g.* the reaction with methanol was carried out at 90°C. and under 40 atm. pressure (acetylene and nitrogen in equal amounts). Vinylation of alcohols in the vapour phase was found not to be so generally applicable.

Acetylene and phenols

The reaction between isobutyl phenol and acetylene to give an oxystyrene which, when polymerised, was known as *Koresin*,

was worked on an industrial scale to the extent of 100 tons/month. In this case zinc naphthenate was used as a catalyst and the reaction was carried out in an autoclave at 20 atm. and 230°C.

Cyclopolyolefines

One of the most interesting achievements of the German acetylene team was the polymerisation of acetylene to cyclo-octatetraene. It is recommended that the reaction be carried out in a steel autoclave at 80°C. and under a pressure of 20 atm. (5 atm. nitrogen and 15 atm. acetylene) with stirring for 24 hr. The product is filtered and the filtrate fractionated, preferably at reduced pressure, to yield:

C_8H_8	b.p.	142–143/760 mm	Golden yellow
$C_{10}H_{10}$	b.p.	190–195/760 mm	Deep yellow
$C_{12}H_{12}$	b.p.	230–235/760 mm	Light yellow
Azulene	m.p.	99.5°C.	

At 80°C., the hydrocarbon mixture is formed in 90% yield on acetylene consumed and the product contains about 80% cyclo-octatetraene and 15 to 20% of the C_{10}, C_{12} and azulene fractions. In respect of applications, most of the work so far carried out was of a speculative nature and it was interrupted in its early stages. Attention should be given, however, to exploiting the novel features of the 8-membered rings, not hitherto readily available, as well as attempting to convert the cyclo-octane derivatives into other compounds of proven usefulness.

The higher polymers

The exact structures of $C_{10}H_{10}$ and $C_{12}H_{12}$ are still in doubt. The claim, attributed to Kuhn, that the $C_{12}H_{12}$ fraction (containing small amounts of azulene) inhibits the growth of certain pathogenic bacteria in concentrations of $1/10^5$ stands in need of confirmation.

Reaction with carbon monoxide

(1) **In the presence of nickel compounds.** The reaction of acetylene and carbon monoxide was developed by Reppe and his co-workers at Ludwigshafen and has given rise to a number of potentially important processes, although these have have not yet been sufficiently developed to permit commercial scale production. In the first instance the reaction of acetylene and carbon monoxide in the presence of nickel or nickel carbonyl and aqueous hydrochloric acid gave acrylic acid, and similarly in the presence of other compounds containing easily replaceable hydrogen atoms, the corresponding derivatives of acrylic acid were obtained. Phenylacetylene gave α-phenol-acrylic acid and phenylmethylacetylene gave a mixture of α-phenylcrotonic acid and α-methylcinnamic acid, and it was therefore assumed that the acetylene reaction proceeded with the intermediate formation of cyclopropenone (no experimental evidence for this):

$$C_2H_2 + CO \longrightarrow \underset{CO}{\overset{CH=CH}{\diagup\diagdown}} \xrightarrow{H_2O} CH_2{:}\,CH\,COOH$$

The reaction with carbon monoxide was found to be applicable to all acetylenic compounds and could be used with nickel carbonyl in stoichiometric quantities or catalytically using carbon monoxide and metals or metallic derivatives capable of forming carbonyls.

(2) **In the presence of iron carbonyl hydride.** The reaction of acetylene and carbon monoxide in the presence of iron carbonyl hydride, $Fe(CO)_4H_2$, and water or an alcohol gave a 20 to 30% yield of hydroquinone.

The reaction could be carried out in the presence of a base, ethanolamine, although this was not essential:

$$2C_2H_2 + 3CO + H_2O \longrightarrow \underset{OH}{\overset{OH}{\langle\rangle}} + CO_2$$

Reaction with carbonyl compounds

A variety of aldehydes may be reacted with acetylene in the presence of copper acetylide to give the corresponding acetylenic alcohols. The reaction did not work with ketones.

Reaction with carbonyl compounds in the presence of amines

At temperatures up to 120°C. and high pressures, acetylene reacts with amines and carbonyl compounds to yield substituted propargylamines:

$$C_2H_2 + (CH_3)_2\,CO + (C_2H_5)_2NH \longrightarrow HC{:}\,C.C.(CH_3)_2N(C_2H_5)_2 + H_2O$$

The catalyst employed on this class of reaction is an acetylide of group I or II metal.

Diacetylene

Diacetylene was a by-product from the arc method of manufacture of acetylene at Hüls, and it occurred in the crude product in concentrations of up to 7%. It was separated, together with vinylacetylene, methylacetylene and ethylacetylene, by oil scrubbing, or better by low-temperature distillation.

Research at Hüls has been directed towards finding outlets for diacetylene, although nothing of exceptional interest has emerged. The main reactions are as follows:

$$\begin{array}{l} \qquad\qquad [RR'C(OH).C{:}\,C.]_2 \\ BR'CO \nearrow \\ HC{:}\,C.C{:}\,CH \xrightarrow{ROH} RO.CH{:}\,CH.C{:}\,CH \\ RR'N.CH_2OH \searrow \\ \qquad\qquad RR'N.CH_2.C{:}\,C.C{:}\,CH \\ \qquad\qquad \xrightarrow{H'} CHO.CH_2'C{:}\,CH \end{array}$$

Carbon blacks

Acetylene black is derived from the spontaneous decomposition, by electrical means, of pre-heated or compressed acetylene.

Carbon blacks are mainly used in the production of tyres and other rubber products, but smaller amounts are also used for lacquers, inks and gramophone records. Acetylene black, however, differs from the blacks described above in its remarkable effect on the electrical resistivity of rubber. The incorporation of about 30% of acetylene black in rubber can cause the specific resistivity to fall from 10^{14} down to 10^2 ohms/cm., whereas a similar proportion of the other gas blacks only causes a drop to 10^8 ohms/cm. This unique property has led to the use of acetylene black in the compounding of anti-static or 'conducting' rubbers and also in the manufacture of dry-cells. Grades of thermal-type carbon black were also produced as by-products from the arc process.

General assessment

The considerable German contribution to our knowledge of acetylene chemistry was largely due to their necessity for the use of acetylene as the keystone of their chemical industry. This necessity does not exist in this country and the U.S.A., and one should therefore accept many of the German claims with reserve. An outstanding example is the manufacture of ethylene by hydrogenation of acetylene, which was carried out in Germany on a scale approaching 50,000 tons/year, but which could not be seriously considered in any of the Allied countries today.

The production of acetylene by the arc or carbide routes requires very large quantities of cheap electric power and, if this is not feasible, serious consideration should be given to the processes involving the thermal cracking of methane and other saturated hydrocarbons, in the presence or absence of oxygen.

Perhaps the most important German contribution to acetylene chemistry was the successful manipulation of acetylene under pressure. Detailed instructions were provided for the operation of many acetylene pressure reactions varying from the laboratory scale to the production of butinediol at the rate of 21,500 tons/year, and it is difficult to estimate the effect that this work will have on future research in this field.

There are but few aspects of vinyl polymers where the German research could be said to have been more successful than that carried out in the Allied countries, but special mention should be made of a new type of fibre derived from polyurethanes which had found considerable applications in Germany, especially for bristles. These polymers should be carefully assessed. Much of the speculative German research work on acetylenic compounds was directed at the synthesis of polymer intermediates and especially those for polyamides. Many of these intermediates have already acquired considerable importance, *e.g.* butinediol, butanediol, tetrahydrofuran, butyrolactone, adiponitrile and adipic acid, and careful costings will have to be made in order to assess finally

(*Concluded on page* 488)

Graphical Representation of Extraction Processes

By A. V. Brancker, Ph.D.

Graphical methods of representing equilibria in ternary and quaternary liquid systems are described in this article, and practical examples based on the equilateral triangle and regular tetrahedron are discussed. These graphical representation methods can be extended to the design of extraction equipment.

FEW processes have a wider range of application than solvent extraction, and considerable advances have been made in the industrial development of this method of separating the constituents of liquid solutions. Extraction processes, for example, are used for the recovery of phenols from effluent liquors, the separation of azeotropic mixtures, the dehydration of acetic acid, the recovery of penicillin and dewaxing and refining petroleum oils.

The method of fractional distribution has been used by Jantzen[1] for the separation of isomeric quinoline bases from coal tar. Cornish and co-workers[2] have also employed it for the purification of vitamins.

The theoretical aspects of liquid-liquid extraction have been studied by Hunter and Nash[3, 4, 5, 6, 7] and discussed by Evans[8] and Underwood.[9] The analogy between distillation and extraction processed have been considered by Saal and Van Dyck,[10] Thiele,[11] Varteressian and Fenske,[12, 13, 14] Randall and Longtin.[15, 16] A comprehensive review of solvent extraction for 1948 is given by Elgin.[17]

Most of the foregoing papers are mainly introductory to the fundamental aspects of extraction processes. However, in the work by Brancker, Hunter and Nash,[18, 19, 20] and Pratt,[21] ternary and quaternary systems have been considered in some detail using practical examples. The graphical methods used in these cases and the results obtained will now be discussed.

Classification of solvent processes

Solvent extraction processes may be broadly divided into four main classes, namely:

(1) Wherein a single solvent is used and the solvent extract and raffinate form a three-component or ternary system.

(2) Wherein two miscible solvents are used and the two solvents, the extract and raffinate form a four-component or quaternary system.

(3) Wherein two immiscible solvents are used and the system is quaternary.

(4) Wherein a combined solvent or solvent mixture and a solid absorbent are used.

In class 1 may be grouped systems such as acetic acid—chloroform—water, or nitrobenzene—petroleum extracts—raffinate. In class 2 fall such systems as SO_2—benzol—extract—raffinate, or acetone—water—vinyl acetate—acetaldehyde. An example of the systems in class 3 is afforded by the *Duo-Sol* process in which the two immiscible solvents are propane and cresol.

In class 4 systems an organic solvent such as benzene is absorbed on a solid like charcoal, for the extraction of phenol from aqueous solutions.[22] These systems, however, are outside the range of the present discussion.

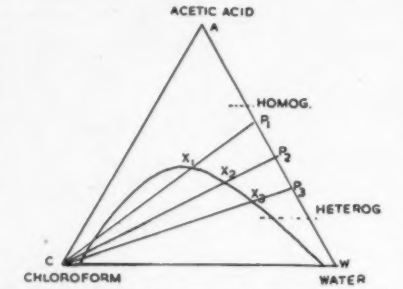


Fig. 1. Triangular co-ordinates in equilateral triangles for the closed system of acetic acid/chloroform/water.

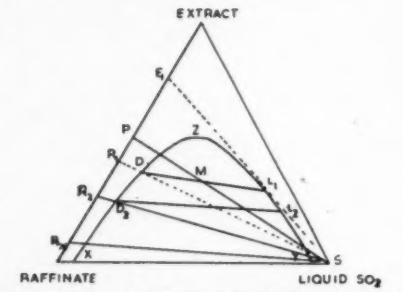


Fig. 2. Closed system of liquid SO_2/extract oil/raffinate oil.

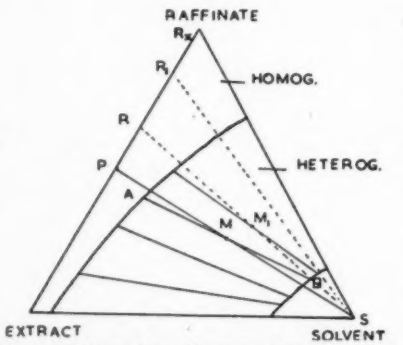


Fig. 3. Extraction diagram for kerosine treated with ethyl alcohol.

In the representation of mixed liquid systems it is customary to employ an equilateral triangle for ternary mixtures and a regular tetrahedron or triangular prism in the case of four components.

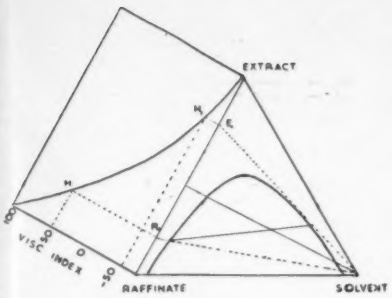
Ternary equilibria

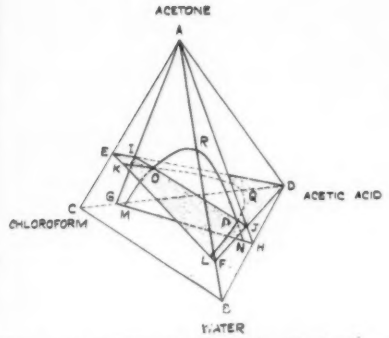
When a system is influenced by two variables, say temperature and pressure, the relationship between them can be represented on rectangular co-ordinates. If, however, three variables are involved and no constant ratio exists between any two, rectangular co-ordinates cannot be used and recourse is had to triangular co-ordinates. The most practical form of triangular co-ordinates is that afforded by the equilateral triangle shown in Fig. 1 for the system acetic acid—chloroform—water. The main features in this method of representation are the equilibrium or binodal curve demarcating the heterogeneous and homogeneous zones, and the tie lines joining the compositions of the two phases in equilibrium.

Figs. 1 and 2 represent what are known as the closed system, where the tie lines initially parallel to the base of the triangle shorten and converge to a critical point on the equilibrium curve. This system may be compared with the open system shown in Fig. 3. The main difference between these two cases is that in a closed system extraction is limited by the tangent ES to the equilibrium curve of Fig. 2.

In order to obtain the equilibrium curve shown in Fig. 1, known mixtures, P_1, P_2, P_3, of acetic acid and water are quantitatively titrated with chloroform until the initially clear solution becomes turbid. The compositions of the turbid mixtures are then located on the equilateral triangle at points X_1, X_2, X_3, and part of the equilibrium curve is constructed. This process may then be repeated by titrating known mixtures of chloroform and acetic acid with water. Tie lines on the equilibrium curve may be determined by mixing the three components in known proportions, separating the two phases and analysing both for percentages of the three constituents.

The determination of tie lines is frequently a laborious process, and methods have been proposed by Brancker[19] and Bachman[23] wherein, from an accurate knowledge of at least two tie lines, others may be interpolated on a straight-line graph. This special chart[19] has been tested and found to hold for some 33 ternary systems.





Figs. 4, 5, 6 (top to bottom). Various extraction processes described in the text.

Application of ternary equilibria

In Fig. 2 is depicted a system composed of liquid SO_2—extract oil—raffinate oil. Let P represent the composition of an oil in terms of extract and raffinate constituents. If this oil is treated with liquid SO_2 the composition of the resultant mixture will move along SP. If 50% solvent is added to the oil the composition of the resultant mixture may be represented on PS by M, where MP=MS. As M is in the heterogeneous region the oil-solvent mixture will separate into a raffinate phase and an extract phase of compositions D_1 and L_1 respectively, where D_1L is a tie line. If solvent is removed from D_1 and L_1 the compositions of the two separate phases will move respectively along D_1R_1 and L_1E_1 to give a solvent-free extract E_1 and raffinate R_1. If, now, the raffinate R_1 is again treated with 50% solvent, a second mixture M_1 will be obtained which will separate into extract phase L_2 and raffinate phase D_2. Extraction, therefore, of the raffinate phase may proceed in this manner by successive additions of solvent until the operating line SR_x coincides with a tie line. In the case of the extract E_1 further solvent treatment is not possible, as SE_1 is the tangent to the equilibrium curve XYZ.

Comparing this system with that of Fig. 3, which is formed, for example, when kerosine is treated with 95% ethyl alcohol, there is theoretically no limit to extraction provided the operating lines SR, SR_1 do not coincide with a tie line. Thus, as before, a kerosine of composition P if treated with 50% ethyl alcohol will form a mixture of composition M which will separate into a raffinate phase B and an extract phase A.

Successive treatments can be represented on the lines SR_1 SR_2 . . . $_x$ until theoretically SR_x coincides with the side of the triangle. In the case of oils the criteria of extraction are the physical properties such as viscosity indices (V.I.), viscosity gravity constants (V.G.C.), pour points, aniline points, etc. In Fig. 4 a rectangular graph has been constructed on the side of the triangle on which is shown a V.I. *versus* oil composition curve H H_1. By means of this curve the viscosity indices of the solvent-free extracts and raffinates can be ascertained and the course of the extraction followed.

A practical method of the foregoing method of representation is afforded by the data given in Table 1 for an oil of V.G.C. 0.8553 treated with acetic acid at 25°C.

In this case the V.G.C. was plotted on the auxiliary rectangular graph.

TABLE 1. EQUILIBRIUM DATA FOR OIL (V.G.C. 0.8553) ACETIC ACID AT 25°C.

Complex		*Upper Phase*		*Lower Phase*	
Acetic acid wt. %	*Oil, wt. %*	*Acetic acid, wt. %*	*V.G.C. of solvent-free oil*	*Acetic acid, wt. %*	*V.G.C. of solvent-free oil*
29.68	70.32	11.65	0.8529	89.32	0.9231
45.83	54.17	10.67	0.8486	90.61	0.9365
58.89	41.11	10.07	0.8455	92.00	0.9408
63.36	36.64	9.62	0.8418	93.03	0.9532
78.50	21.50	9.99	0.8364	95.98	0.9623
90.01	9.99	9.85	0.8299	98.00	0.9687

Quaternary equilibria

In Fig. 5, a quaternary system composed of acetic acid—acetone—chloroform—water is schematically illustrated. As may be seen, the two ternary systems, acetone—chloroform—water and acetic acid—chloroform—water lie respectively on a face and the base of the tetrahedron. By joining the two ternary equilibrium curves a frustum is formed inside the tetrahedron. This frustum is cut by the vertical triangle extending from the acetone apex to the tetrahedron base. The intersection of this triangle with the frustum demarcates a quaternary equilibrium curve.

In an investigation of this particular system Brancker, Hunter and Nash[20] established that the quaternary tie line OP, in Fig. 6, was situated on the line of intersection of planes AGH and ELD. The bases of these two planes are respectively IJ and EF, which each contain a ternary tie line. From this observation it followed that quaternary equilibria data could be predicted from a knowledge of the two ternary systems. A study of the figure will indicate that data for the quaternary system can be geometrically established if the two ternary systems are known.

The foregoing method has now been applied to the system acetone—water—vinyl acetate—acetaldehyde investigated by Pratt.[21] Some of the experimental data for this quaternary system, which are of high accuracy, are given in Table 2, together with results calculated from tie lines in the two-ternary system. The geometrical technique employed is outside the intended scope of the present discussion and will be published in a separate article.

As may be seen, however, close agreement is obtained between experimental

TABLE 2

Quaternary tie line	(E) *Experimental* (C) *Calculated*	ACETATE LAYER *Weight percentages*				WATER LAYER *Weight percentages*			
		Vinyl acetate	*Water*	*Acetone*	*Acetaldehyde*	*Vinyl acetate*	*Water*	*Acetone*	*Acetaldehyde*
1	E	86.9	1.4	7.1	4.6	2.3	88.3	4.7	4.7
	C	86.0	1.7	7.4	4.9	2.6	88.0	4.5	4.9
2	E	81.5	1.7	12.0	4.8	3.1	84.4	8.0	4.5
	C	81.2	1.8	11.9	5.1	3.0	84.0	8.2	4.8
4	E	61.8	3.4	21.3	13.4	4.7	70.2	13.4	11.7
	C	61.7	3.8	21.2	13.3	4.8	70.3	12.9	12.0
5	E	65.8	2.8	12.3	19.1	4.0	72.8	7.4	15.8
	C	65.6	2.9	12.8	18.7	3.5	73.1	7.7	15.7
6	E	83.2	1.7	6.5	8.5	2.8	83.8	4.1	9.3
	C	83.3	1.8	6.4	8.5	2.5	84.2	4.1	9.2
7	E	82.1	1.8	9.6	6.5	2.7	85.0	7.4	4.9
	C	82.0	1.9	9.8	6.3	2.6	84.8	7.6	5.0

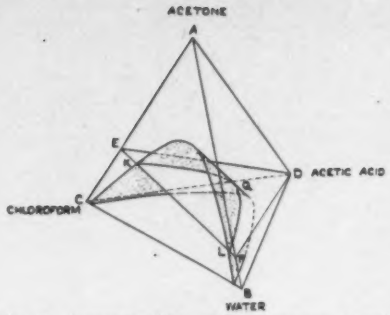


Fig. 7. Investigation of quaternary equilibria.

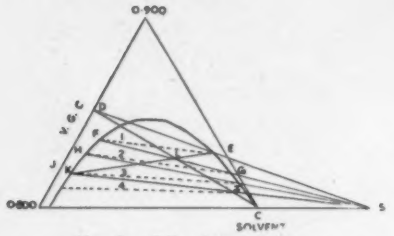


Fig. 8. Oil solvent system.

and calculated results, although deviations were reported by Pratt[21] using Hunter's method.[7]

Extraction stages computation

In many ways an extraction column functions similarly to a fractionating tower. Consider, for example, the oil solvent system and the hypothetical extraction column shown in Figs. 8 and 9.

Let D represent the composition of the inlet oil feed P, where W_{n+1} is the inlet solvent flowing counter-current to P, and W_1 the exit extract phase.

Also, let the desired V.G.C. of the solvent-treated oil be represented by J.

Taking a weight balance on the column

(*entering*) $P+W_{n+1}=P_n+W_1$ (*leaving*)

where P_n is the raffinate phase and W_1 the extract phase.

If the composition of the feed-solvent mixture is L, then,

$$DL/DC=W_{n+1}/P$$

and

$$KL/LE=W_1/P_n$$

where K and E are respectively the compositions of raffinate and extract phases, P_n and W_1.

The extract phase E, however, is in equilibrium with a raffinate phase F located by the tie line EF. EF, therefore, represents the first stage of the extraction process. In order to obtain subsequent stages a special construction is used. The base of triangle is extended, and a point S located by extending DE. With S as a construction point, FS is drawn, cutting the equilibrium curve at G. The tie line GH then fixes the second stage of extraction. Similarly SH, cutting the curve at I, fixes the third stage as the tie line IK. The limit of extraction is reached when the construction line from S coincides with a tie line, which is after some four stages.

In Table 3, data are given for the counter-current extraction of two lubricating oil stocks with nitrobenzene at 10°C., whereby a comparison may be drawn between experimental and calculated results.

Summary

Methods of graphical representation which apply normally to data obtained in the laboratory can be extended to the design of extraction equipment. Here, however, little information is available on column performance, although it may be expected that much unpublished work has been accomplished. References on this aspect of solvent extraction are contained fairly fully in Pratt and Glover's paper.[21]

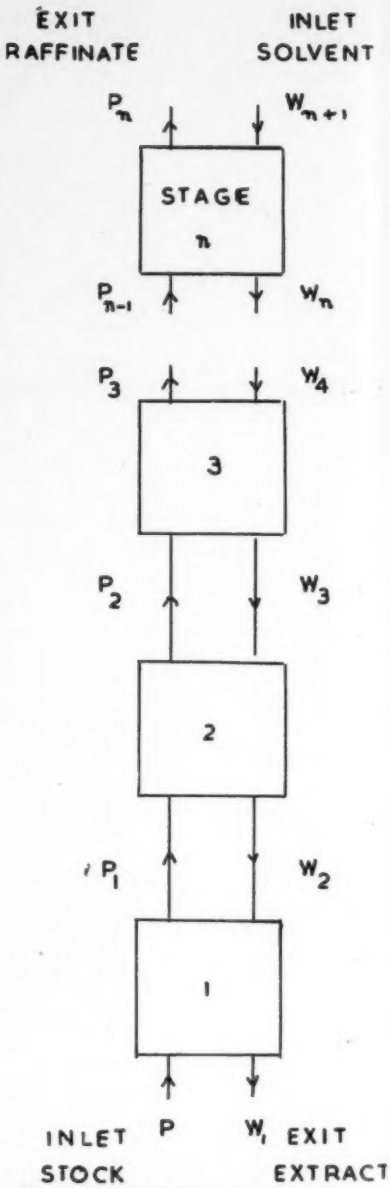


Fig. 9. Hypothetical extraction column.

REFERENCES

[1]Jantzen: 'Das fraktionierte Distillieren und das fraktionierte Verteilen,' *Dechema Monographie*, Band 5, **48**, 81, Berlin Verlag Chemie, 1932.
[2]Cornish, Archibald, Murphy and Evans: *Ind. Eng. Chem.*, 1934, **26**, 397.
[3]Hunter and Nash: *Ind. Eng. Chem.*, 1935, **27**, 836.
[4]*Idem.*: *J.S.C.I.*, 1932, **51**, 285T.
[5]*Idem.*: *Ibid.*, 1934, **53**, 95T.
[6]Fallah, Hunter and Nash: *Ibid.*, 1935, **54**, 49T.
[7]Hunter: *Ind. Eng. Chem.*, 1942, **34**, 963.
[8]Evans: *Ibid.*, 1934, **26**, 439.
[9]Underwood: *Ind. Chemist*, 1934, **10**, 128.
[10]Saal and Van Dyck: World Petr. Congress, London, 1933, **2**, 253.
[11]Thiele: *Ind. Eng. Chem.*, 1935, **27**, 392.
[12]Varteressian and Fenske: *Ibid.*, 1936, **28**, 928.
[13]*Idem*: *Ibid.*, 1936, **28**, 1353.
[14]*Idem.*: *Ibid.*, 1937, **29**, 270.
[15]Randall and Longtin: *Ibid.*, 1938, **30**, 1188.
[16]*Idem.*: *Ibid.*, 1939, **31**, 1295.
[17]Elgin: *Ind. Eng. Chem.*, 1949, **41**, 358.
[18]Brancker, Hunter and Nash: *Ibid.*, *An. Ed.*, 1940, **12**, 35.
[19]*Idem.*: *Ibid.*, 1941, **33**, 88.
[20]*Idem.*: *J. Phys. Chem.*, 1940, **44**, 683.
[21]Pratt and Glover: Paper to Inst. Chem. Eng., N.W. Branch, April 6, 1946.
[22]Stage and Schultze: Hobart Publishing Co., Washington, 1947.
[23]Bachman: *Ind. Eng. Chem., An. Ed.*, 1940, **12**, 39.

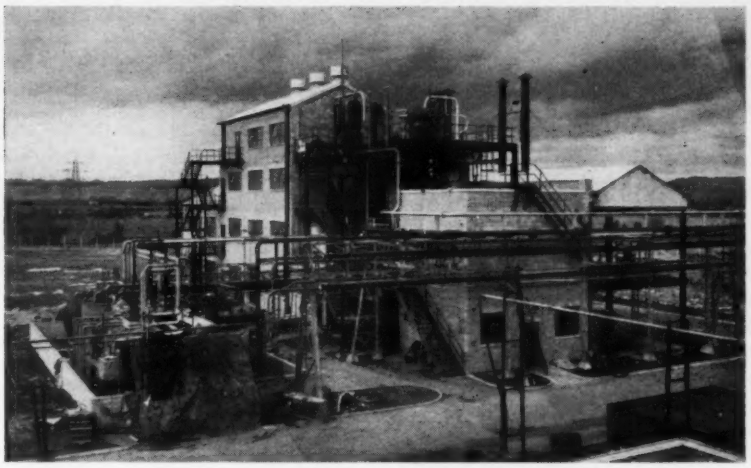
TABLE 3. COUNTER-CURRENT EXTRACTION OF LUBRICATING OIL STOCKS WITH NITROBENZENE AT 10°C. (*Hunter*)

Oil stock treated	*Volumes of solvent per 100 volumes of oil stock used*	RAFFINATE LAYER					EXTRACT LAYER					
		V.G.C. of solvent-free oil	*Solvent-free oil as volume % of original stock*		*Volume % of solvent in layer*		*V.G.C. of solvent-free oil*		*Solvent-free oil as volume % of original stock*		*Volume % of solvent in layer*	
			Act.	*Calc.*	*Act.*	*Calc.*	*Act.*	*Calc.*	*Act.*	*Calc.*	*Act.*	*Calc.*
Semi-paraffinic stock V.G.C. 0.853	53.3	0.817	54.8	57.7	14.2	14.0	0.899	0.901	45.2	44.0	49.8	51.0
	100.0	0.811	49.0	50.5	12.5	12.5	0.895	0.897	51.0	49.5	64.8	65.0
	136.4	0.807	44.0	47.5	10.8	12.5	0.889	0.895	56.0	52.5	70.1	71.1
	185.0	0.804	37.7	42.0	12.5	13.0	0.884	0.890	62.3	57.0	74.3	75.5
	375.0	0.799	27.9	23.0	9.0	14.5	0.874	0.879	72.1	72.0	83.7	84.0
Stock A, V.G.C. 0.867	65.0	0.845	56.6	59.3	11.1	16.0	0.897	0.898	43.4	41.4	57.0	56.0
	98.0	0.835	52.5	51.4	13.2	14.0	0.902	0.901	47.5	48.2	65.5	65.0
	188.0	0.831	37.9	40.4	11.2	13.0	0.887	0.891	62.1	60.5	74.7	75.0

Monsanto's New Works in South Wales

AT Newport, Monmouthshire, four years' work and the investment of close on £3,000,000 has resulted in the construction by Monsanto Chemicals Ltd. of a model chemical works, the design of which embodies several highly original chemical engineering techniques. Rather more than half the site is occupied by the factory at present and complete development is being actively planned. This is the second Monsanto factory in Britain. The other is at Ruabon, North Wales.

The Newport factory manufactures products which previously were imported. These are styrene plastic, detergents, oil additives, preservatives, fungicides and chlorinated diphenyls. Though all vary widely in their properties, there are many common factors among the raw materials, processes and equipment concerned, giving a general unity to the Newport works. Considerable use is made of oil products as starting materials, and other major raw materials are chlorine, caustic, phenol and sulphuric acid.



The *Aroclors* (chlorinated diphenyls) plant.

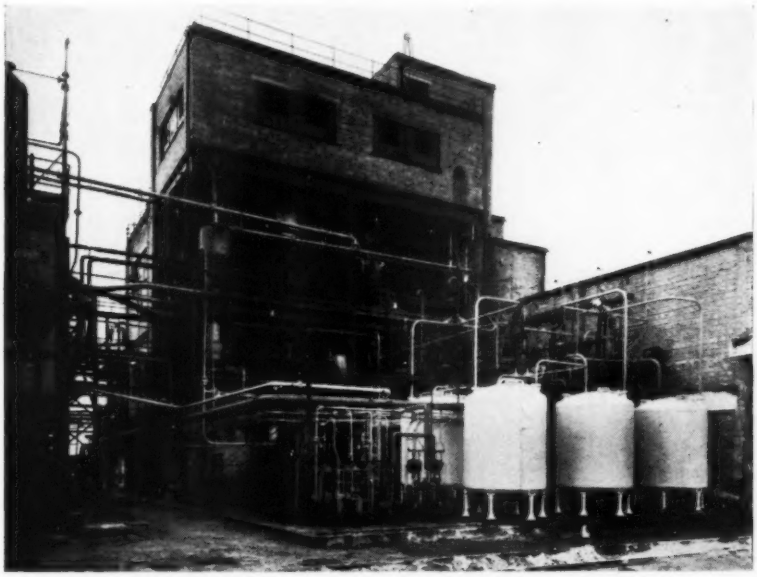
Polystyrene

A light, transparent thermoplastic, *Lustrex*, which has not previously been made in Great Britain in any quantity, belongs to the group of plastics known as the styrenes. Although these substances were among the first plastics to be discovered, difficulties of manufacture have long held up their development. The main problem was how to produce, economically, styrene of sufficiently high purity. Modern oil technology provided the answer, and styrene plastic was produced commercially in 1937. The seizure of rubber plantations by Japan in 1942 led to rapid progress in the production of styrene, which is the basis of synthetic rubber manufacture. Polystyrene is claimed to cost less per unit volume than any other mouldable thermoplastic resin. It has a tensile strength of up to 7,000 lb./sq.in. and extremely low moisture absorption. Its high dielectric strength makes it useful as a 'fused quartz' type of insulation for radio frequencies. A particularly interesting property is its ability to transmit light round curved sections.

The styrene monomer, the clear liquid which is polymerised into *Lustrex*, must be of exceptional purity. The admixture of as little as 0.002% of styrene homologues can produce an unsatisfactory product.

Lustrex, with a wide range of colours, is sold as a coarse crystalline powder or as small glassy pellets.

Production flow of polystyrene manufacture is from top to bottom of a building dominated by a 120-ft. tower. This unit was commissioned in August 1950. Manufacture starts with the polymerisation of the water-white liquid styrene monomer. The resulting clear polystyrene is next mixed with pigments in a row of double cone blenders. The speed of rotation of the blenders is critical for proper dispersion of the pigment. The coloured polystyrene is finally extruded into a water bath, whence it emerges to a cutter which chops it into pellets. The extrusion process is necessary to ensure thorough dispersion of the pigments. Eighteen standard colours are made and special shades can be produced if required. Colour matching is performed on a recording spectrophotometer of American manufacture, one of the very few in use in this country.



The rear view of the *Santomerse* plant.

Detergents

The *Santomerse* plant, including tank farm, production section and warehouse, is by far the largest in the factory.

Its overall length is 1,000 ft. and it is 150 ft. wide. This was the first plant to come into operation, and huge quantities of dodecyl benzene sulphonate detergent have been turned out since it was started up in August 1949.

The plant consists of two duplicate units, comprising storage vessels, chlorinating vessels, nickel fractionating stills, sulphonating vessels, slurry tanks and five large drum driers. The raw materials are extremely corrosive and extensive use has been made of monel, nickel and silver and glass-lined equipment. Certain of the storage tanks are lined with rubber. Other measures against corrosion have been to minimise the escape of hydrochloric acid and chlorine and the sheathing of cables with PVC.

Production begins with the chlorination of kerosine, consisting of a mixture of fresh and recycled material. Benzene is then continuously alkylated with the chlor-

kerosine, using a catalyst to control alkylation. The feeding of the catalyst is a delicate process because of its tendency to cake. Off gases are scrubbed and piped to an absorption unit for the recovery of hydrochloric acid. The alkylbenzene is sulphonated to produce *Santomerse*. Sulphuric acid and alkylbenzene are reacted continuously in the sulphonation stage and waste acid is separated from the alkyl benzene sulphonic acid. This waste sulphuric acid is sold to steelworks for pickling.

The alkylbenzene sulphonic acid is neutralised with caustic soda to form a slurry. The *p*H of the slurry is adjusted, and it is then filtered and fed to the drum driers. The dried *Santomerse* is sifted and packed directly as flake and powder.

Automatic control

Although it has a large output the Newport factory employs less than 1,000 operatives and executives. The secret of this is the use of some 4,000 instruments to control processes. The most spectacular concentration of instruments is in the control room of the *Santomerse* plant, the four walls of which are covered with scores of meters—principally temperature, pressure, vacuum, depth and flow recorders. Above the central panel is the ' enunciator board,' which lists each stage of the process by name. Should there occur any breakdown in the plant, a light appears on the appropriate panel to show the site of the trouble. Coloured lights also indicate the stage which each operation has reached, and there are safety controls which operate in any emergency. Thus the engineer in charge has a complete picture of processing in each part of the plant.

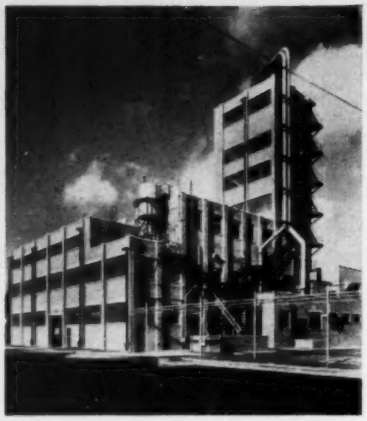
'Aroclors'

This group of chlorinated diphenyls ranges from mobile liquids to clear waxes. The boiling points of the waxes extend to 1,270°C. The lowest solidification temperature of the liquids is 35°C. As chlorination increases, the inflammability of these compounds lessens and about three-quarters of them do not burn at all. The most inflammable has a flash point as high as 140°C. They are used in polishes, paints, varnishes, lacquers, plastics, transformer oils and brake fluids and as heat exchangers.

Starting material for the manufacture of *Aroclors* is benzene. This is thermally condensed to give diphenyl, which is chlorinated and distilled to give various grades of *Aroclors*. Accurate temperature control is essential to prevent the accumulation of impurities. This plant is the latest to come into operation.

Preservatives and weedkillers

Near the *Aroclor* plant is the unit in which chlorine and phenol are reacted to give a range of preservatives and weedkillers, namely *Santobrite* (sodium pentachlorophenate), *Santophen* and *Permasan*



Exterior of the *Lustrex* polystyrene plant.

(pentachlorophenol). This plant was commissioned in March 1950. The process is basically simply and the plant straightforward. To produce the sodium salt, chlorinated phenol is dissolved in caustic soda. The latter is water-soluble, the other grades being soluble only in mineral oil. Owing to the steel drum shortage, these products are being packed in plywood casks. Export shipments are sealed in polythene bags before being placed into the casks.

Oil additives

In the south-east corner of the factory stands the oil additives plant, a three-storey building, 150 ft. long by 60 ft. wide. This has several interesting points of design. Materials are distributed by lift from ground-level, and each floor is of open grill-work to aid ventilation. The ground floor is tiled and drained, to facilitate cleaning. Overhead cranes give quick handling of heavy equipment.

Oil additives have a wide range of properties. Three principal types which are manufactured at Newport are *Santolube* 203*A*, a detergent which keeps engines clean and eliminates ring-sticking; *Santolube* 394*C*, an antioxidant; and *Santopour B*, which keeps oil fluid at low temperatures. Since, however, there are other types for which modern engine design may create a demand, and also certain new additives which are already under test in the Monsanto research laboratories, the plant at Newport is designed as a flexible multi-purpose unit.

The essential principle of multi-purpose design is to break down various manufacturing processes to a series of fundamental reactions—chlorination, sulphonation, neutralisation and so on. Stations are designed for each of these reactions in such a way that they can be linked together in any order required and their working conditions varied at will. By this system the Newport oil additives plant can produce not only any one of the three additives already scheduled for manufacture, but could be switched at short notice to the making of other similar substances, including those still on the research programme.

Since each additive has a special purpose, there is considerable variation in structure. *Santolube* 203*A*, a detergent which was designed to dissolve carbonaceous deposits, is in general formation rather like *Santomerse*, except that it is soluble in oil instead of in water. In other words, the molecule has the same long-chain hydrocarbon component, but the polar group is oil-seeking. *Santolube* 394*C* is a complex sulphur-containing organic compound with a remarkable capacity for arresting the breakdown of lubricating oils by oxidation during actual engine use.

The chlorine plant

The large quantities of chlorine required by the various production processes are to be made in an electrolytic plant of advanced design. Brine is passed to the chlorine cell building, where it will be electrolysed in a long series of cells. This operation simultaneously produces caustic soda. The power house, adjoining the electrolytic plant, houses the diesel-electric generators which provide the power for the process.

Services

Steam for manufacturing processes is distributed as required through overhead lines. Five boilers, coal-fired and automatically stoked, supply steam at a pressure of 150 lb./sq.in. to ring-mains, from which it is drawn off to steam-coils, pumps and other equipment. There are also oil-fired high-pressure water-tube boilers which deliver steam at 450 lb./sq.in. for use in high-temperature distillation columns.

Heavy traction throughout the works is done by a ' fireless ' steam locomotive which is charged as required at the steam mains, and can then work for some hours without recharging.

Overhauling and testing of the many instruments which control the chemical processes is carried out in a large instrument workshop. There is also an engineering workshop capable of doing most types of maintenance work and small-scale construction and of devising parts for use in experimental plant.

Effluent disposal

An efficient effluent plant has been designed to ensure safe disposal of all waste liquors. These are neutralised if necessary, or given other treatment, run out into large settling tanks, and pumped far out into the estuary of the Usk. They are only discharged on the ebb tide.

'I.C.E.' November

Articles include :

Pumping Practice by A. Flindle, M.I.Mech.E.

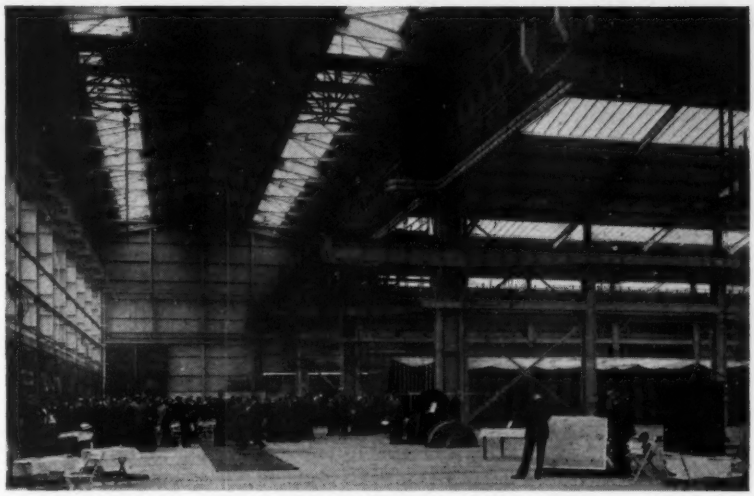
An Index of Mixing by John A. Dukes, A.R.I.C.

The Manufacture of Cemented Tungsten Carbide

Chemical and Engineering Research in Australia

Power-Gas Celebrate 50 Years of Chemical Engineering

THIS year marks the golden jubilee of the Power-Gas Corporation Ltd., Stockton-on-Tees. A special jubilee edition of the Corporation's magazine, *Concord*, traces the history of the firm from the day in 1873 when, attracted to Tees-side by railway facilities, abundant labour, supplies of iron and a rising demand for engineering products, William Ashmore and his brother-in-law, Samuel While, first founded the works under the name of Ashmore & While.



The constructional shop in the new South Works of the Power-Gas Corporation was the scene of the Golden Jubilee celebrations.

Gas-holders

The company specialised in building gas-holders, and one of their earliest erections, No. 1 gas-holder at the Middlesbrough Gas Works, built in 1874, is still giving satisfactory service today. For ten years the business grew rapidly and the original three-acre site was extended to eight acres until personal difficulties caused the dissolution of the partnership in December 1883. This threatened to prevent the further growth of the company until, in 1885, further finance was made available by the formation of a new company under the title of Ashmore, Benson, Pease & Co. Ltd.

The seven founder directors of the firm were all well known and respected on Tees-side and included William Whitwell, the first chairman, who was also owner of William Whitwell & Co., Thornaby Iron Works, the first firm on Tees-side to import foreign ore; Robert Braithwaite Benson and his son, Robert Seymour Benson, who became the first secretary of the company; and two half-brothers, Henry Fell Pease and Edward Lloyd Pease. Whitwell and the Pease brothers were Quakers and the Quaker characteristic of uprightness in all things was evident in the dealings of the company from the start, early minutes of the directors' meetings even indicating that the firm was prepared to lose substantial orders rather than stoop to underhand methods of trading.

As previously stated, the trade of Ashmore & While had developed principally as gasholder makers, and the extent to which they developed their gasholder production may be gathered from the fact that, in 1873, the works was described as the Hope Iron Works but, by 1885, it had come to be known as the Gasholder Works. This title was not used for long before the name Parkfield Works was adopted because the works had been built on the fringe of the town in an area known as Park Field. A catalogue published in 1887 gives the full range of the company's products and, while the first 65 pages are occupied with gas works plant, the remaining pages include steam and hand pumps, Lancashire and vertical boilers, railway- and footbridges, iron hand barrows, lead ladles, spades and forks. A method of securing the parallel movement of the floating gasholder was devised by the firm and became known as Pease's patent cable system of gasholder control. The system was patented in 1888 and was widely used. Before the end of the century the firm was able to invite prospective clients to visit any of the engineers of undertakings at which 52 gasholders had been erected.

Among the subsidiary interests of the firm was Pease's Tubular Construction Syndicate Ltd., formed to carry out work on a patent type of fireproof flooring, a specimen of which was erected in an old brick-kiln. Chemical engineering, as distinct from gas, entered into the activities of the company in 1897 when they began the design and construction of oxygen-making plant with patents made available to them by the A.F. Process Co. Ltd. In 1899 the business of Miller & Co., Stockton, was acquired for the manufacture of electric accumulators, though this activity was dropped in 1908. In January 1900, the company opened their first London office at 181 Queen Victoria Street and in the same month negotiations were begun with Dr. Ludwig Mond which resulted in the incorporation of the Power-Gas Corporation Ltd. on July 16, 1901. On November 12, 1901, the newly formed corporation acquired the business of Ashmore, Benson, Pease & Co. Ltd. for the manufacture of the special gas plant necessary for the production of power-gas (Mond gas).

Power-Gas Corporation formed

When the Power-Gas Corporation was formed the British rights in the process were sold to the corporation and a public issue of shares brought an overwhelming response. However, only a relatively small sum was required and the Monds deferred their own interest in any profits. Most of the new money was spent on improving Parkfield Works and, when, in a few years, the setback to the fortunes of the firm occurred, the Monds bore the brunt of the capital losses. Dr. Mond also made a free gift to the corporation of all the foreign businesses and patents and personally backed several enterprises formed to exploit these inventions, such as the South Staffordshire Mond Gas Co. Ltd., Ammonia Finance Ltd. and others. His son, Alfred Mond, later Lord Melchett, was associated with the company for 15 years, and again from 1922-30. The present chairman, Wilfred Beswick, was also associated with the birth of the corporation. He became a director in 1913 and was chairman from 1939 to 1951.

In 1908 the business of the corporation was transferred from London to Parkfield. In the same year the Mersey Engine & Gas Producer Co. was acquired, which specialised in suction gas plant. In 1918 the corporation acquired the business of Lymn & Rambush, gas and chemical engineers, thereby enlisting the services of Arthur H. Lymn, who has been a director of the corporation ever since, and N. E. Rambush, who came to Parkfield as chief engineer and is the present managing director and chairman.

Steady increase in trade had gradually absorbed all the manufacturing capacity of William Ashmore's 8-acre site and, in the 1920s, additional sites and workshops were acquired nearby. The Bowesfield Foundry was occupied in 1927 and the Imperial

Boiler Works in 1928. The former was equipped for the manufacture of gasholders, which relieved some of the pressure at Parkfield.

In 1928 a new department was opened for blast furnace plant under the managership of Major W. R. Brown. This move was linked with the formation of schemes of collaboration with the leading American designers of blast furnace plant—the Freyn Engineering Co. of Chicago. The first new Freyn design blast furnace was built by Ashmores for the Ford Motor Co. at Dagenham and reached a new level in the mechanisation and automatic control which have now become features of every modern furnace. This furnace held all British records for output and coke consumption until much larger furnaces were built a dozen or so years later. Few of those who established the blast furnace section in 1928 believed that it would eventually challenge in importance the gas plant manufacturing side of the business.

Expansion

In 1933 arrangements were concluded with the Meehanite Metal Corporation of the U.S. for the manufacture of Meehanite castings, and Parkfield became the first works in Britain to manufacture these castings under licence from the International Meehanite Metal Co. Ltd. In 1936 the Semet-Solvay organisation in the U.S. made available their experience in connection with plant for water-gas production, while in 1938 Davison & Partner Ltd. was absorbed into the Power-Gas Corporation which, with the combined experience and resources of these organisations, soon made a name for itself as manufacturers of water-gas plant for town's gas.

During the war the resources of the corporation were at the Government's disposal and among undertakings for which they were in part responsible were the Mulberry Harbour, components for the Bailey Bridge, the construction of hydrogen plant for the R.A.F. balloon barrage and of producer gas plants providing emergency fuel resources for factories on essential work. The war years also saw the formation of Ashmore, Benson, Pease & Co., Africa (Pty.) Ltd., and the Power-Gas Corporation (Australasia) (Pty.) Ltd., while in 1945 an arrangement was entered into with the Chemical Construction Corporation of the U.S. enabling the company to take advantage of their experience and designs in the manufacture and erection of synthetic ammonia plants.

100-acre site

In 1948 the directors decided that, though the 8-acre site had now grown to 23 acres, it was still too small and that a completely new works should be built on a new 100-acre site nearby. The new South Works, as they are to be called, will be constructed over a period of many years, and it is intended, if circumstances permit, to transfer the whole of Parkfield equipment and personnel to the new site in stages, the first to move being the constructional department.

It is surely a matter for encouragement to note that the first 50 years of the Power-Gas Corporation was started with a works reconstruction scheme, and the second half of the century has been marked by the unveiling of a stone in the walls of the yet unfinished South Works. Earlier this year the controlling interest was acquired in the latest associate company, Rose, Downs & Thompson Ltd. of Hull, which firm is renowned for the manufacture of plant for the edible oil industry.

U.S. Chemical Statistics

Supposing one wanted to discover how much, say, formaldehyde was made in Britain in 1949 and, furthermore, the number of producers and the amount and value of their sales. Perhaps it would be possible to glean this information, but several sources would have to be consulted and much time would be required. To get the same statistics of other countries' production would be an even more difficult task. However, there would be one shining exception—the United States. In that country the Manufacturing Chemists' Association Inc. publishes a unique book of chemical facts and figures, the third edition of which has appeared,* in which all the above information could be found together with similar facts about hundreds of other chemicals, chemical products and raw materials. It also contains import and export statistics. There are also financial records for 100 leading chemical process companies on an annual basis for the ten years 1939-49, besides a special section on employment and wages, including data on average earnings, length of work week, number of wage earners, labour turnover and work stoppages.

The majority of the statistics in this monumental collection of facts and figures are for the period 1946-49, but it also contains partial data for the first six months of 1950.

In addition to U.S. data, the book contains Canadian statistics, including a newly added section on minerals.

Like its predecessors, this edition is part of the Association's plan to publish a continuing record of chemical industry statistics. Previous editions covered the periods 1929-39 and 1940-45. If chemical manufacturers' associations in other major chemical-producing countries followed this excellent example, an extremely valuable global picture of chemical production would be built up very quickly.

* *Chemical Facts and Figures—Useful Information and Statistics relating to the Chemical and Allied Products Industries.* Third edition. Compiled by the Manufacturing Chemists' Association, Inc., Washington, U.S.A., pp. 419, $3.

Chemical Engineering Costs

In engineering practice the question, 'How much will it cost?' is almost as important as 'Will it work?'. This may not always be appreciated by the young engineer, often because cost data, unlike physical data, are not easily obtainable; certainly not in a readily usable form. In this book* the authors have provided a single source of many of the cost data of importance to the chemical engineer. Since it deals exclusively with American cost data, the book is of limited use outside the United States. Nevertheless, it is worth noting, especially if it inspires authors in other countries to compile similar data for their own particular circumstances. Should anyone be thus contemplating such a compilation, he will be interested in the authors' answer to one of the objections frequently raised to collections of cost data, that is that costs are constantly changing. This, according to the authors, is not as serious as some believe, because for most cost calculations that the chemical engineer is called on to make an accuracy of $\pm 10\%$ is usually adequate. Furthermore, it is said to be easy to bring cost data up to date by the application of factors based upon prevailing material and labour costs.

Several experts have collaborated in the writing of this book, the general arrangement being a chapter devoted to each of the major items of equipment, evaporators, heat exchangers, filters, centrifuges, etc.

* *Chemical Engineering Costs*, by O. T. Zimmerman and I. Lavine. Industrial Research Service, New Hampshire, U.S.A., 1950, pp. 419, including index.

Acetylene in Germany

(*Concluded from page* 481)

the new methods based on acetylene. The reactions of carbon monoxide with acetylene, leading to the formation of acrylic esters, would also appear to have useful potentialities.

Cyclo-octatetraene

Even more speculative was the research carried out on the polymerisation of acetylene to cyclo-octatetraene. As this hydrocarbon is now potentially available in considerable quantity, further research must be directed towards exploiting the properties of the derivatives of cyclo-octane and cyclo-octatetraene, hitherto regarded as laboratory curiosities.

Given cheap acetylene, the way is clear to the industrial utilisation of the many varied intermediates which chemical research has revealed in recent years in Great Britain, the U.S.A., France and Russia as well as in Germany.

There is no doubt that many further applications still await discovery.

British Titan's New Laboratories

The new laboratory building of the British Titan Products Co. Ltd. is on the company's factory site at Billingham, where production started in 1934 with an annual output of 2,000 tons of titanium oxide. The Billingham factory now produces approximately 16,000 tons of anatase pigment p.a. Together with rutile pigments, now being manufactured at Grimsby and Burnie, in Tasmania, and with a new factory in Travancore and also extensions to the Grimsby factory nearing completion, the total annual output of the company by the end of 1952 will be in the region of 40,000 tons. The new facilities for research into and technical control over titanium oxide manufacture are described in this article.

THE total floor space of the new laboratory building is 20,000 sq. ft., compared with that of the old laboratories, including the analytical research department which is now housed separately, of 6,200 sq. ft.

There are two main floors and the laboratories and offices are situated on either side of the central corridors which run the full length of each floor. Except in the corridors, lighting is by fluorescent tubes throughout.

The building is air-conditioned throughout; only one room has windows which may be opened. The air is fed into each room *via* louvres in the duct walls. It is cleaned and cooled by water sprays and cotton filters, and is heated when necessary. The system is designed to give ten complete changes/hr. A smaller unit, in the same building, conditions the air supplied to the constant-temperature and -humidity room, and controls it to ± 1°F. and $\pm 1\%$ RH.

Paint laboratory equipped for the preparation of paints by all techniques at present in use.

General-purpose laboratories

Four laboratories of similar design have been finished for general work including research on the 'wet' part of the process. The benches are all tiled and are fitted with gas, water, electricity and vacuum points. Each of the remainder of the rooms has been designed and equipped for a specific purpose.

In the first general-purpose laboratory research is carried out on all stages of the process from the solution of the ilmenite to the precipitation and purification of the hydrated TiO_2 pulp. This includes the studies on the preparation and effect of nuclei which plays such an important part in the manufacture of pigments with optimum properties.

The purified TiO_2 pulp, being too small in particle size to have the required pigmentary properties, has to be calcined to cause crystal growth to the optimum size, which is of the order of the wavelength of visible light. This step is carried out in a battery of thermostatically controlled electric muffles installed in the next laboratory. The effect of various after-treatments on the performance of pigments is also investigated.

Besides the normal control tests such as tone, brightness, tinting strength and fading resistance, paint-making equipment is provided for testing experimental pigments under conditions of outdoor exposure and accelerated weathering. The equipment includes an edge runner mill, a Smith triple roll mill, ball mills, a Hoover Muller and an accelerated weathering machine of novel design.

Semi-technical laboratory

A large tiled room has been provided for semi-technical-scale investigations of the titanium oxide process from ore grinding to pigment milling. The apparatus so far installed is capable of handling much larger quantities than normal laboratory equipment. Sufficient free space has been left for the erection of further semi-technical apparatus when required.

Physical laboratory

This is a general-purpose physical laboratory, part of which has been equipped as a workshop. The equipment used here includes an ultrasonic generator, which is used for dispersing pigments before examination in the electron microscope. It has also provided valuable information regarding the behaviour of titanium pigments in various media connected with its applications in industry. There is also a sputtering apparatus, the principal use of which is to shadow specimens, before examination in the electron microscope, by exposing them to beams of metal atoms at a pre-determined angle in a high vacuum.

Microscopy and *x*-ray laboratories

In order to obtain the maximum benefits from the unique properties of titanium oxide, the laboratories have been equipped with the most up-to-date instruments for studying crystal structure and particle size. The *x*-ray equipment is used to differentiate between and estimate the proportions of anatase and rutile in a pigment. The development of the rutile modification to any desired degree is essential for controlling pigment properties, and *x*-ray methods are the only ones available for estimating the relative amounts of anatase and rutile with certainty.

With the Metropolitan Vickers' general-purpose unit the diffraction patterns are recorded photographically and, by measuring the intensity of the lines by means of a micro-photometer, the proportion of anatase and rutile can be estimated. This instrument is very versatile and is put to many other uses besides rutile estimation, *e.g.* examination of minerals.

The Philips' Geiger counter *x*-ray spectrometer is used specifically for analysis of powder mixture, and the technique developed for its use is such that a rutile estimation can be made in 5 min. to an accuracy of $\pm 0.5\%$. This model is also used in the factory control laboratories for routine control of production of rutile pigments to ensure its uniform high durability. Advantage has been taken of the electronic circuits of the apparatus, in conjunction with special Geiger counters, to utilise radioactive trace elements in certain analytical investigations.

The Cooke Troughton metallurgical microscope is of great value for the examination and photography of subjects which do not require the high resolving power of the electron microscope, *e.g.* ores, paint films, etc.

Owing to the extremely small particle

size of titanium oxide pigments it was not possible before the acquisition of the electron microscope to see and hence know with certainty the shape and size of the pigment particle. The instrument is a Philips model, and was the second of this kind to be installed in this country. It is capable of magnification up to 200,000 diam. Already much information has been gained about the size and shape of pigment particles and about intermediate products, the nature of which hitherto was a matter of conjecture. The instrument has also been used to examine the breakdown of the surface of paint films after weathering. A unique feature is that an individual particle can be isolated and positively identified by the production of electron diffraction pattern.

Paint laboratory

This laboratory is equipped for the preparation of paints by all the techniques at present used in the industry and the best conditions for the milling of titanium oxide pigments with various types of machinery are investigated. The paints used for evaluation of other pigment properties are also made here. The equipment includes a Cox and a Smith triple roll mill, a refining mill, a Beken Duplex mixer, a Premier colloid mill, a heavy-duty high-speed stirrer, a Sharples centrifuge and a Keenok 6-in. Uniroll. A separate room is equipped with trundlers for ball milling.

Paint application room

This room is tiled throughout and fitted with waterproof benches in order that walls, benches and floors can be washed down regularly to ensure a dust-free atmosphere for paint application, which includes brushing out and dipping by means of an automatic dipping machine.

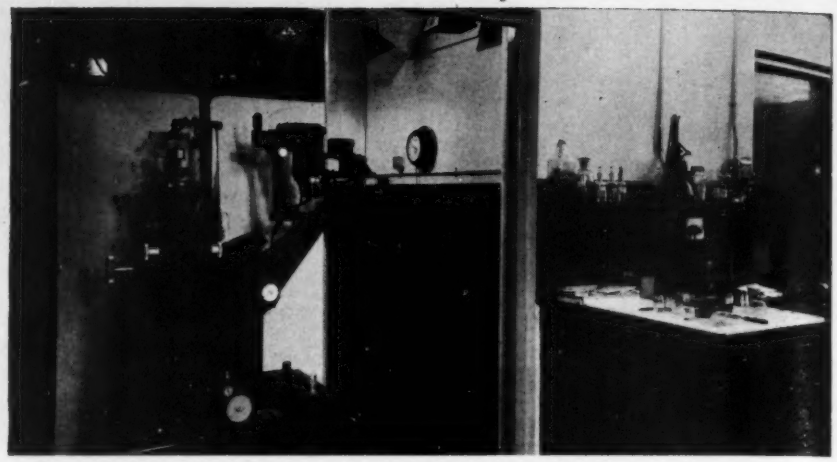
A spray booth is situated in the roof pent-house. A varnish kitchen is also provided in the pent-house in which are made nearly all the varnishes used by the paint department.

Constant-temperature and -humidity room

This room is used to carry out those tests on pigment, paint and paper which require constant conditions of temperature and relative humidity. For pigment testing a granite triple-roll mill and edge-runner mill are installed, and also a Hoover Muller. Instruments for measuring drying times, viscosity and storage characteristics are provided.

Paper laboratory

A beater and sheet-making apparatus enables paper to be made from the pulp stage. The water supplied to the paper department is treated with coagulents and filtered to render it suitable for paper-making. A proof-printing press in the same room is used for the evaluation of both paper and inks containing TiO_2.



Microscopy and *x*-ray laboratories.

Physical laboratory

The main items in this laboratory are a rotational viscometer and two photometers, one of which is used for measuring the colour of the pigment, and the other, of lesser accuracy, for rapid measurement of the colours of paints.

Exposure records

A special laboratory is devoted to the regular examination of paint panels during exposure and keeping records of formulations and test results. The same laboratory is responsible for paint testing by accelerated weathering.

Vitreous enamelling laboratory

This laboratory is especially well equipped for development work on vitreous enamels. Smelting and firing furnaces (gas and electric) are in a special furnace room, isolated from the main laboratory where the enamels are milled and tested.

The technical services department has its own analytical laboratory mainly for paint and paper analysis.

A photography room has been provided for recording the appearance of paint films, etc., and other illustration work.

Library

Besides its use as a library, this room is suitably furnished as a conference room and in it the departmental meetings are held. Among the library's accessories are photostat equipment and an epidiascope.

Recent publications

Heavy industrial installations. A selection of interesting installations of various types of plant built by the Power-Gas Corporation Ltd. and Ashmore, Benson, Pease & Co. in Great Britain is listed in a recently issued booklet. The installations include blast furnaces, carburetted water-gas plants, producer-gas plants, gasholders, hydrogen plants, lime kilns and crystallisers. Brief details are given of each of the 69 plants listed and maps are used to indicate their location. Some outstanding examples include the first of the new blast furnaces at the new Margam works of the Steel Co. of Wales as well as the second larger furnace with a hearth diameter of 29 ft. 9 in., believed to be the largest in the U.K. Another furnace of the same size is under construction. Two mechanical carburetted water-gas plants, each of 2,500,000 cu. ft. capacity, are installed at the South Surburban Gas Works in Lower Sydenham and are the first in this country to have automatic hydraulic operation incorporating Lockheed features pioneered by Power-Gas. The first *Krystal* crystalliser built by the companies and the first of the type to be designed for the production of coarse-grained salt is installed at the I.C.I. Salt Division's Stoke works. The quality and size of the product is such that it is hoped that *Krystal* coarse-grained salt will ultimately supersede pan salt. The diversity of their installations is again illustrated by some examples of the general engineering contracting which includes the large penicillin factory of the Distillers Co. Ltd. at Speke where the companies fabricated all the equipment and erected the whole of the plant. This involved the site fabrication and erection of some 60 miles of various sizes of piping, including stainless steel, nickel and *Monel*. A complete lubricating oil plant was dismantled at an east coast site, transported, reconstructed, modernised and re-erected at Stanlow for the Shell Co.

Maintenance of carbon brushes. A booklet giving the brief essentials for the mounting and maintenance of *Morganite* brushes comes from the Morgan Crucible Co. Ltd. It also lists commutator troubles and their causes as well as slip ring troubles.

Water in Industry

Although water is so vital a raw material for chemical manufacture that its availability determines the siting of chemical works, little thought is given to it unless there are difficulties in supply or disposal. These and many other aspects of water supply and utilisation deserve more consideration and with this in mind the Society of Chemical Industry, at their annual meeting in London, devoted several of their technical sessions to the theme of 'Water in Industry.' Here are summaries of four of the papers presented at this symposium.

Water supplies for the U.K. chemical industry

THE availability of water throughout the U.K. was reviewed by Prof. P. G. H. Boswell in relation to the steadily increasing needs of industry and public health. The different purposes for which water is required in the chemical industries allow for the exercise of discretion in the utilisation of the various sources, so that high quality water may be conserved. The scale of the demand, unless it is quite small, now determines the siting of works. Although there are still many districts where works requiring 100,000 to 2,000,000 gal./day can be located, only few lowland areas suitable for the large type of works, using 3,000,000 to 15,000,000 gal./day, remain unsaturated. For obvious economic reasons, works have usually been established in the vicinity of estuaries, and on or near coalfields. In many of these districts competition for water has led to overpumping: legislation has consequently been introduced in order to safeguard the remaining resources. Hydroelectric developments in the upland regions, where water is plentiful, may herald a change in the industrial pattern, but this will be influenced by economic and possibly strategic considerations.

Prof. Boswell then referred to the sources of water supply information available for industrialists and concluded with some information on recent water legislation so far as it concerns those who desire to establish new works or extend old ones; also on the procedure to be adopted where a Ministerial licence is required before underground water may be abstracted.

Industrial waste waters in America

Disposal of industrial waste waters in America was discussed by Dr. F. W. Mohlman, Director of Laboratories, The Sanitary District of Chicago. He described it as a challenge to industry never before fully recognised until recent agitation energised state water boards, initiated regional stream pollution authorities and provided governmental control centred in the U.S. Public Health Service. Public Law 845, passed in 1948, is being implemented by some 14 regional authorities, who consider industrial waste abatement almost as important as sewage pollution abatement. Of 4,409 municipalities and 3,413 industrial plants surveyed, 1,912, or 43%, of the former were discharging untreated waste and of 3,413 factories 1,967, or 57%, were likewise discharging untreated wastes. The Cooke Report, recently submitted to President Truman, discusses the effects of this pollution in reference to 'A Water Policy for the American People.'

Industrial wastes cover a variety of types. In Chicago types of wastes have been studied for the past 16 years, covering some 450 industries, and have been divided into the following classes: packinghouse and stockyards, meat products and sausage casings, rendering works, glue and gelatin, food products, yeast and vinegar, malting, breweries, tanneries, soap, vegetable oils, candy, textiles, paper, coke plants and tar products, pharmaceuticals, dye works, chemicals and viscose casings, steel and iron pickling, electroplating, brass-copper-minerals, rubber - asbestos - enamelling, dairies and milk products, laundries, and miscellaneous. Most types, except paper pulp, distilleries, antibiotics and synthetic rubber plants, are represented in Chicago. However, in the surrounding areas these wastes, plus oil refinery wastes, are present in large concentration and such plants have spent millions for waste abatement.

Nation-wide, industrial wastes are scattered, but are present mostly on the east and west coasts, the Ohio Valley, the Chicago area and the Texas Gulf region, being relatively few west of the Mississippi River.

Technical abatement methods depend upon the flow conditions of the rivers, which vary tremendously. Treatment can vary from neutralisation of acid, screening, settling and chemical precipitation to full-scale biological treatment. For some bays or harbours reaeration alone may satisfy the oxygen demand. Interesting specific examples of varied treatment are: (*a*) Settling, for organic, chemical or metallic waste. (*b*) Screening, for disposal into large rivers. (*c*) High rate biological filters for more rigorous disposal conditions. (*d*) Activated sludge, for practical undiluted disposal.

Salvage of waste in industry is one of the most hopeful possibilities for avoiding the trouble and expense of artificial treatment before discharge. Such salvage as recovery of stock food from starch, antibiotics, cannery, brewery and distillery wastes often obviates the cost of final treatment. American industry still offers economic advantage by careful attention to salvage operations, balanced against sensible utilisation of minimum river flow for disposal of residual wastes. Technical methods of final treatment are legion, but they all cost money. It is a great advantage to discharge industrial wastes into sufficient sewage to provide a suitable biological reservoir for continuous treatment. An industry is fortunate to be located in a large city, but must largely count the cost of treatment as the penalty for location in an independent site, on a small stream or lake, or above a source of water supply. The phenol-taste difficulties of the latter are one of America's most vexatious problems, a great challenge to technicians, but probably made more difficult by unrealistic demands by sanitary authorities, local, national or international.

Corrosion inhibition

Corrosion problems arising from water in chemical industry were discussed by Dr. U. R. Evans, Cambridge University.

Corrosion by cooling water is often combated by inhibitive treatment. Cathodic inhibitors possess limited utility, but anodic inhibitors, including nitrites, chromates, phosphates and emulsifying oils, are highly effective, if added in sufficient quantity. The amount needed increases with the chloride content of the water, and if the inhibitor becomes locally exhausted the attack may be more intense than if no inhibitor had been added. Badly designed plant (containing inaccessible corners), or careless operation leading to accumulation of debris, increases the danger of local exhaustion and intensified corrosion; the use of phosphate-chromate mixtures, or the new benzoate type of inhibitor, diminishes the danger.

Corrosion by boiler water includes pitting caused by oxygen, pitting of the type connected with metallic copper in laminated scale and also caustic cracking; for preventing the latter the sulphate-ratio rule is of questionable utility, but the Purcell-Whirl controlled phosphate process deserves attention.

Treatment of water for high-pressure boilers

The object of boiler plant is to produce a continuous supply of steam of the required purity at low cost. The aim of feedwater treatment is the prevention of steam contamination, and corrosion or the formation of solid deposits likely to cause failure of boilers and ancillary plant, or interruptions

in service. This is done by the correct choice and application of chemicals, and the purer the feedwater the easier it is to achieve this aim. The treatment was described by P. Hamer, of the Alkali Division, I.C.I.

Impurities in steam are gases, *i.e.* ammonia, carbon dioxide and oxygen, and solids, *i.e.* boiler water salts and sometimes silica. They can cause corrosion and deposits in superheaters, steam mains, turbine blades. When condensate is returned to the boiler and the removal of gases is imperfect, corrosion may occur in condensate lines, feedwater heaters, economisers, and even the boiler itself.

The quantity of solid impurities present in steam can be ascertained by continuous sampling, cooling and measurement of the electrical conductivity of the condensed sample, or evaporation to dryness and weighing. Ammonia and carbon dioxide should be removed before measuring conductivity. The conductivity method does not determine silica.

Experience in U.S.A. shows that silica in boiler water may become a special problem at boiler pressures exceeding about 1,000 lb./sq.in. owing to the dissolution of silica or silicic acid in the steam, and the formation of deposits of almost pure silica at the L.P. end of turbines. The laboratory experiments of Straub and Grabowski show that at pressures below 1,000 lb./sq.in. carry over silica by this mechanism is negligible.

The reduction of impurities in steam is secured by choosing a make-up water supply of suitable composition by appropriate chemical treatment of this water, by control of boiler blowdown and boiler water levels and by the use of mechanical devices in the boiler, such as steam scrubbers, cyclone separators and steam washing.

Solid deposits

These may be hard scales or soft sludges, depending on their chemical composition and the temperatures and rates of heat transfer at the surfaces where they form.

At the high ratings employed in modern H.P. boilers the formation of even small amounts of hard scale is dangerous. The scales may contain calcium sulphate, calcium and magnesium silicates, sodium aluminium silicate or sodium iron silicate. The prevention of these scales is in the first place mainly a matter of choice and control of softening process to secure efficient removal of hardness and silica, and this becomes more important as the amount of treated make-up increases. Small amounts of hardness remaining in the boiler feedwater, despite all precautions in the softening process, or as a result of condensate contamination by cooling water, are dealt with by adding phosphate to the boiler water to precipitate the hardness as a soft sludge. Soft deposits of hydrated iron oxide can also be present in boilers owing to corrosion of feed lines, etc.

The accumulation of fair amounts of sludge in boiler tubes can eventually so restrict the water flow that failure takes place owing to overheating. In more highly rated tubes failure may result from localised corrosion underneath sludge. The remedy lies in the improvement of softening efficiency, the rapid detection and elimination of condenser leakage, the prevention of corrosion in feed lines, the removal of unavoidable sludge by blowdown, and, possibly, changes in boiler design or operation to secure higher rates of circulation in the tubes affected.

Soft deposits in preheaters and economisers are usually due to reaction between hardness and the phosphate used for conditioning; it is best, therefore, to inject this into the boiler drum.

Corrosion

The first step in the prevention of corrosion in boilers, feed lines, economisers, etc., is the removal of oxygen from the feedwater. In the author's view physical deoxygenation alone is not sufficient to guarantee the absence of oxygen at all times, and supplementary chemical deoxygenation with sodium sulphite is needed, the amount of sulphite used being sufficient to maintain a concentration of 20 to 40 p.p.m. Na_2SO_3 in the boiler water at all times. There is evidence from America that at pressures of the order of 1,500 lb./sq.in. and above some decomposition of Na_2SO_3 takes place and lower concentrations have to be used.

With efficient deoxygenation the feedwater should not be allowed to become acid, and its *p*H should be kept above 7.5. Ammonia can also be present in feedwater and can corrode copper or copper alloys in preheaters and feed pumps, the copper being carried into the boiler presumably in the form of complex copper ammonium salts, which under certain conditions would be expected to stimulate corrosion of boiler metal. The behaviour of copper salts under boiler conditions, however, has not been studied in detail. Ammonia is derived from nitrogenous material in some treated natural waters used as evaporator feed or direct make-up, or in cooling water. It can be removed by ' break-point ' chlorination of raw water and by rejection of turbine ejector condenser drains.

Distilled water at boiler temperatures attacks steel with formation of ferrous hydroxide and then magnetite, which usually forms a protective layer on the metal surface. If this layer is broken for any reason, mechanical, thermal or chemical, the underlying metal is exposed to further attack.

The presence of boiler water salts at the concentrations normally present might be expected to stimulate attack at breaks in the magnetite layer, but the absence of widespread corrosion in boilers seems to show that the protective layer is usually quickly re-formed in the presence of concentrations of caustic soda normally employed.

At the higher concentrations of salts and caustic soda which are reached at wind and water line in heated tubes, or are believed to occur underneath soft, water-permeable deposits in tubes, re-formation of an adherent protective magnetite layer does not appear so likely, and this may account for many of the cases of localised attack reported.

The use of a mixture of tri- and di-sodium phosphates instead of caustic soda to provide alkalinity in boiler water has been advocated in America by Purcell and Whirl as a means of preventing caustic embrittlement, and they have reported that boilers so treated are also free from corrosion. This is probably due to the fact that iron phosphate is less soluble than ferrous hydroxide. As a means of preventing corrosion alone this method appears worth further trial in high-pressure boilers.

Caustic embrittlement

This type of localised stress corrosion attack has been thoroughly described in the literature. It is usually found in the riveted seams of boiler drums, but has occasionally been reported in tube ends. The author has also had experience of failures in alloy steel bolts in high-pressure boiler blowdown lines owing to cracks attributed to caustic embrittlement. In this case *Calgon* has been added to eliminate caustic soda from the boiler water, as advocated by Purcell and Whirl, for the last three and a half years and appears to have afforded protection. It is, however, expensive when the make-up is high or contains much alkalinity.

Conclusions

The following principles are offered as a guide for the treatment of feed and boiler water for high-pressure boilers:

(1) The choice of raw water supply and softening treatment to produce a final mixed feedwater having the following characteristics:

(*a*) Low dissolved solids—to reduce boiler blowdown.

(*b*) Low hardness—to avoid sludge and scale in the boiler.

(*c*) Low bicarbonate (HCO_3)—to prevent corrosion by steam and condensate.

(*d*) Low alumina and silica—to prevent scale in boilers and turbines.

(2) Conditioning treatment to be added to the final feedwater or direct to the boiler drum. This treatment is suggested even for boilers employing feedwater consisting of turbine condensate and evaporated make-up.

(*a*) Addition of phosphates direct to the boiler drum—to prevent scale by small amounts of calcium and magnesium salts.

(*b*) Deaeration of feedwater by physical means to reduce the oxygen content to at least 0.02 ml./litre (0.03 p.p.m. O_2) followed by chemical deoxygenation by continuous addition of sodium sulphite to the feedwater, in amount sufficient to combine

(*Concluded on page* 497)

Recent American Chemical Engineering Patent Claims

A GREAT number of claims filed at the U.S. Patent Office are concerned with chemical engineering inventions. Here is a selection of some interesting patent specifications which were published recently.

Evaporation and distillation

Volatile constituents are separated from a discrete distillable material by vertically vibrating the material in cycles. Each cycle includes a mechanically actuated downward stroke against an upwardly directed yielding tension, and an upward stroke substantially free of the mechanical actuation but actuated by the energy stored in the yielding tension during the downward stroke. The material under treatment is subjected during the vibration to a predetermined degree of heat sufficient for rapidly and uniformly bringing each particle to the desired end temperature. This causes the vibrated and heated material rapidly to release its volatile constituents.—2,525,051, *K. L. Storrs, Salt Lake City, Utah.*

In high-vacuum evaporation, a film of liquid is caused to move adjacent to a relatively cool condensing surface in a rarefied atmosphere. The film and the condensing surfaces are separated by unobstructed space, and the film is heated by contact with an evaporation surface. This latter surface has a tightly fitting, readily removable, flexible, pliable, permeable covering sleeve of inert, acid-resistant, nonmetallic mineral mesh fabric, such as *Fibreglass* cloth. This covering serves to distribute the distilland and to retain tarry and gummy residues formed at the evaporation surface, so that such residue will not be collected on the evaporation surface itself.—2,530,376, *U.S. Secretary of Agriculture.*

Centrifugal separator

A centrifugal separator for separating granular solids of different densities, present as a pulp in a liquid carrier, employs a liquid medium of intermediate density which allows the separation of particles, *e.g.* minerals, down to 100 mesh or finer. The cylindrical shell of the separator is provided with an overflow outlet for maintaining a constant level of medium in the shell and a second overflow outlet for maintaining a constant level of the liquid carrier over the medium. The separating medium, together with the denser granules, is maintained by the rotation of the shell in an outer annular layer, while the less dense granules are maintained in an inner annular layer of the carrier. A discharge opening for granules is provided in each tapered end portion of the shell. The layer of denser granules is fed by a worm from under the carrier to one of these openings, while the layer of less dense granules is fed by a second worm within the carrier over the denser granules in the medium to the other opening.—2,528,974, *Process Development Co.*

Vessel for oxidation reactions

A reaction vessel, used particularly for oxidation reactions in the gaseous phase, such as the oxidation of gaseous hydrocarbons, allows close control of the reaction. All parts of the reaction vessel are arranged free to expand and contract under temperature changes without the use of expansion joints, pipe bends and the like. The discharge tube of the vessel extends a substantial distance within the external shell of the vessel and is spaced therefrom. One of a number of inlets into the vessel communicates with the space formed between the external shell and the discharge tube, while another of the inlets extends partly within the discharge tube and is adjustable as to its position relative to this tube.—2,530,527, *Celanese Corp. of America.*

Heat exchange

The heat-transfer part of a heat exchanger for liquids consists of a set of flat, hollow, rectangular elements disposed in parallel and spaced apart from each other, through which elements one of the liquids is conducted. These elements are so attached to frames holding their ends together that the elements, together with the frames, may be removed as a unit for inspection or cleansing.—2,526,157, *T. Ramén, Stockholm.*

For transferring heat and producing refrigeration, trifluorobromomethane (CF_3Br) is condensed and then evaporated in the vicinity of a body to be cooled.—2,531,373, *Minnesota Mining and Manufacturing Co.*

Ion exchange

In the treatment of solution with granular ion exchange material wherein this material cyclically passes through an exhaustion zone, a regeneration zone, and a rinsing zone, a mixing zone is maintained functionally interposed between the rinsing and the regenerating zones and substantially free from any of the exchange material in transit through the zones. Fresh regenerant chemical is continuously added to spent rinse water in the mixing zone to produce fresh regenerant solution. This solution is passed upward through the regeneration zone and discharged as spent regenerant solution from the top end thereof.—2,528,099, *The Dorr Co.*

Desiccation

A desiccating apparatus is provided with a lower inverted cone in its treating chamber. The material to be treated—*i.e.* a material dispersed or dissolved in water or the like—is sprayed centrally of the chamber.

Heated air is introduced tangentially of the chamber to cause a swirling action and a centrally rising air column. A transverse partition is provided across an upper portion of the chamber and has a central opening and an outer trough. A baffle is arranged between this opening and an upper central air exhaust port in the chamber defining a tortuous passage for effluent air. Liquid to be desiccated is sprayed into this tortuous passage.—2,525,224, *H. S. Kaiser Co.*

Solvent extraction

In solvent extraction, a liquid solvent is introduced into the uppermost of a vertical series of settling zones and conducted downward along this series. The liquid to be extracted, which is lighter than the solvent, is simultaneously conducted upward along the series of zones so that multi-stage extraction of components is effected.

Commingling of the descending and ascending liquids is effected at each zone, and the resulting mixture is passed along a horizontal course through the zone. The flowing mixture is divided within the zone into separate concurrent, superposed streams of reduced depth. An extract phase settles along the bottom of each stream while the lighter raffinate stratifies along the top thereof. Means are provided for further treatment of the divided heavier and lighter phases to ensure complete extraction.—2,528,426, *The Lummus Co.*

Treating solids with liquid

An apparatus for treating solid material with liquid allows the material to be agitated in the liquid by being moved cyclically therein. The agitating means is of such a type that synchronism of movement of the material and the liquid is avoided.

A rocker arm supported above the tank of the apparatus makes oscillatory movements about a horizontal axis and is provided with means for suspending material to be treated from the rocker into the tank. The movement of the rocker arm oscillating in cycles is stopped twice in each cycle for intervals of unequal duration, so that the treating liquid, *e.g.* a pickling medium, will pass to an appreciable degree through and around the material under treatment.—2,528,851, *American Steel and Wire Co. of New Jersey.*

New Plant and Equipment

Clip-type valve

A valve designed primarily for the chemical industry, made by Warren, Morrison Ltd., is based on the laboratory clip principle. It consists of a natural or synthetic rubber tube with end flanges enclosed in a body with a clamping mechanism. The advantages claimed for this

Closing mechanism of the valve can be seen in this photograph where the body of the valve has been removed.

design are: the fluid is completely isolated from contact with the metal body or working parts and thus a wide range of chemicals can be handled without either risk of corrosion of the valve or contamination of the fluid passing through it. When it is fully open the valve offers no more flow resistance than a section of pipe and a streamline flow is allowed even when the valve is throttled. It is particularly suited to the handling of abrasives, and for this purpose a special range of tubes is available; the straight-through full-bore feature also makes the valve especially suitable for handling slurries and materials with a tendency to clog or build up in other types of valve. The life of the tube, of course, depends upon the application to which the valve is put, but it is normally several years, and the tube is easily replaceable. The renewal of the tube is the equivalent of relining the body of a rubber, glass or other type of lined valve.

High performance refractory

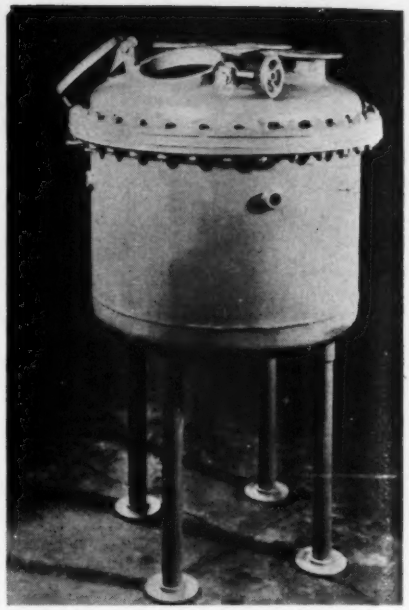
Claimed to have a greater factor of safety at high temperatures, to give longer life and to reduce maintenance costs, a new refractory now being marketed by the Morgan Crucible Co. Ltd. is described briefly in a recently published leaflet. The approximate chemical analysis is silica 52 to 53%, alumina 43 to 44%, iron oxide less than 1%, magnesia less than 1%, and lime, potash and soda together about 1.5%. Not only is the percentage of silica and alumina unusually high, but such impurities as are present are found in relatively small quantities and, what is claimed to be equally important, they are evenly distributed throughout the brick. The refractory, Morgan M.R.1, is fired at a temperature that is claimed to ensure volume stability under all conditions of normal loading at temperatures up to 1,600°C. Softening under load does not commence until 1,600 to 1,650°C., 10% subsidence taking place at a temperature of 1,750°C. Morgan M.R.1 is suitable for any position where firebrick is used and particularly recommended for copper-refining furnaces, foundry cupolas, glass tank regenerator furnace settings, boilers, crucibles and billet and slab reheating furnaces.

Silver-lined M.S. plant

Silver is one of the most important corrosion-resistant metals. It withstands the action of organic acids and very many mineral acids and salts, may be used in the presence of halogens and their compounds, is unaffected by alkali and is particularly suitable for complex corrosive conditions in which both organic and inorganic acids are present (see table on this page).

Silver's low mechanical strength and its comparatively high cost have tended in the past to limit its use to those applications in which its exceptional properties have been essential and to act as deterrents to more widespread employment. These disadvantages are obviously overcome without loss of efficiency by a composite form of construction in which a base metal of high strength supports a greatly reduced volume of noble metal.

Johnson, Matthey & Co. Ltd. have now commenced the production of plant fabricated of silver-lined mild steel and are manufacturing a range of jacketed and single-shell vessels, either open or with bolted-on covers, with working capacities of 1 gal. up to 250 gal.



[Photo: Johnson, Matthey & Co. Ltd.

Typical 50-gal. silver-lined reaction vessel now in production.

Portable blowers

Electric portable blowers for industrial use, *e.g.* blowing out dust from machinery, cleaning stock bins, etc., are supplied by the Martindale Electric Co. Ltd. Attachments include heater units and suction units for powder recovery, etc.

New Plant and Equipment
Fill in the Enquiry Coupon on page 498 for further details of the equipment and plant described in
INTERNATIONAL CHEMICAL ENGINEERING.

CORROSION TESTS ON CHEMICALLY PURE SILVER

Corroding medium	*Conc. %*	*Temp. °C.*	*Weight loss g./cm.²/24 hr.*
Acetic acid vapour	100	118	0.00003
Acetic acid: boiling liquid	99.5	118	0.00003
Acetic acid: liquid-vapour junction	99.5	118	0.00005
Aluminium chloride	30	100	0.00005
Aluminium fluoride	Saturated solution	100	Slight gain
Crude *m*- and *p*-cresol	—	70	Nil
Citric acid	5	100	0.0001
Hydrochloric acid*	5	35	0.00002
Lactic acid	50	120	0.001
Nitric acid†	—	—	—
Phenol: dry boiling liquid	100	182	Nil
Phenol: boiling liquid	90	180	0.00015
Phosphoric acid	10	100	Nil
Phosphoric acid	85	120	0.003
Phosphoric acid	90	250	0.05
Sodium chloride: aerated solution	3	20	0.000005
Sodium hydroxide	70	110	0.00001
Sulphuric acid: boiling liquid	10	102	0.00002
Sulphuric acid: boiling liquid	20	104	0.00004
Sulphuric acid: boiling liquid	60	140	0.0003
Sulphuric acid: boiling liquid	80	220	Rapidly attacked

* Rate of attack increases with concentration and temperature.
† Silver is readily attacked at all concentrations and temperatures.

World News

GREAT BRITAIN

Copper prices reduced

The Ministry of Materials announced on September 13 a reduction in the price of electrolytic copper of £7, making the price £227 per long ton delivered consumers' works. This reduction is made possible by the Ministry's decision not to buy copper for the time being at prices exceeding the American f.a.s. export price, as quoted in the *Engineering and Mining Journal*.

Discounts, premiums on special shapes and the limitations on forward purchasing arrangements announced by the Ministry of Supply on May 1 1951, remain unaltered.

The Ministry of Materials' buying price for rough copper in slabs of from 2 to 3 cwts. remains unchanged.

The Minister of Supply has made an order making corresponding adjustments in the controlled maximum prices of scrap and unwrought brass from September 13.

Metals Economy Advisory Committee

The Minister of Supply, in conjunction with the Lord Privy Seal as Minister of Materials, has appointed an Advisory Committee on Metals Economy to assist him to ensure the most economical use of metals in the engineering industry and in the defence programme. Mr. D. A. Oliver, director of research to the B.S.A. group of companies, who recently became Metals Economy Adviser to the Minister, is chairman of the committee.

The terms of reference of the committee are: 'To bring under review, in consultation with the various Government and industrial authorities, concerned, ways of economising in the use of scarce metals in the design, specification and the manufacturing process of metal goods for both rearmament and civil purposes, and to advise the Government how it can best assist in promoting such developments.'

As measures of economy in non-ferrous metals have an effect on and are affected by questions of supply of these metals, the committee will report to the Minister of Materials as well as to the Minister of Supply.

More industrial alcohol

Increased supplies of industrial alcohol and methylated spirits have enabled restrictions on their sales, imposed last February, to be removed. This has been announced by the Distillers Co., Ltd., and the Methylating Co., Ltd.

AUSTRIA

Benzyl cellulose production

The Benzylcellulose GmbH. factory at Hallein is to step up its output of benzyl cellulose from 2,000 to 15,000 kg./month by the installation of a new kneading machine. It is hoped to export some 50% of the latter quantity. The factory was built in 1949 with an E.R.P. credit of 1,850,000 schillings and an original capital of 5,000,000 schillings. It is claimed to be the only producer of benzyl cellulose in the world.

Benzyl cellulose is claimed to have advantages over other synthetic materials. It is elastic and heat-resisting; it is a better insulator than porcelain; and it can be used as a lacquer and varnish base and also as a protective coating. Benzyl cellulose lacquer and varnish is acid-proof, heat-resisting and non-stretching and it is easily sprayed. In compressed form it is suitable for normal usages of plastics. It is manufactured from cellulose, chlorine and toluol, all of which are available in Austria, and was first produced by I. G. Farben.

New tar distillery ready soon

A new tar distillery, belonging to the United Austrian Iron & Steel Works at Linz, will be partially completed and start production before the end of this year. All sections of the plant to be completed by the end of 1952.

Monthly output of crude tar at present amounts to 2,500 tons. When the new plant goes into operation, it will greatly improve Austria's supply of high-quality road tar, as well as of other distillation products used by the chemical and pharmaceutical industries.

GERMANY

Special cement plant

A new blast furnace slag cement works of the Steine und Erde GmbH. will start production in the near future with an annual output of some 100,000 tons. The company is an affiliate of the Reichswerke and has been financed with funds supplied under the employment programme. It will use a dismantled Thomas slag granulation plant as well as 16 reinforced concrete shelters, each with a capacity of 1,000 tons, which were initially earmarked for demolition.

The granulated blast furnace slag, electric power and blast furnace gas required for the manufacture of this special cement will be available from the Reichswerke, so that the two plants will be complementary.

HOLLAND

Plasoleum plant

The Drachtster Latex plant of De Bruin and Berends Ltd. at Drachten, Friesland, is the first in Holland to start the manufacture of *Plasoleum*, a product consisting mainly of latex and river sand, and is to be extended to cope with increased output. It is claimed that *Plasoleum* can be used as a floor covering, for bridge membranes, wharf footings, etc., as damp-resisting material, and as an anti-corrosion material in machinery, pipes, etc.

IRISH REPUBLIC

Petrol-from-turf scheme

Research is being undertaken on a scheme to produce petrol from turf. Scientists employed by the Irish Turf Board now believe that gasification of turf on a commercial basis is feasible.

A £60,000 research scheme is being financed jointly by the Government of the Republic of Ireland and E.C.A. The scheme has been worked out by research scientists connected with the Turf Board, the Irish State Chemical Co., the Irish Institute of Industrial Research and Standards, the Irish Electricity Supply Board and officials of the Irish Department of Industry and Commerce and E.C.A.

It is expected that a year, or even more, may elapse before the productivity of the research scheme can be determined.

The contribution by E.C.A. is to amount to $30,000, but the hiring of technicians and all non-dollar expenditure will be controlled by the Government of Ireland.

It has been estimated that one-third of the Republic's annual petrol supplies, or approximately 25,000,000 gal., may be produced, requiring a turf output of 1,250,000 tons p.a.

ITALY

New petroleum refinery

The Italian Ministry of Commerce and Industry has granted a concession for a new petroleum refinery with an annual capacity of 80,000 tons to the Societa Anzionaria Raffinazione, which was recently incorporated with the Gruppo Italiano Petrolifero.

The Minister for Industry has also granted a concession to CICSA, a Trieste company, for building a refinery at Porto Nogaro, with a capacity of 200,000 tons annually. Other large petroleum companies have also applied for authorisation to enlarge their refineries.

FRANCE

Oil refinery enlarged

A new topping plant has been put into operation at the Donges refinery of Raffineries Françaises de Pétrole de l'Atlantique. This will raise the capacity of the refinery to 1,200,000 tons a year, which is nearly four times the pre-war capacity. The installation of the new plant will enable the refinery to raise its output to the limit for which it has been granted refining authorisations.

New petrochemical company

A company which will produce and market petroleum-base chemicals and petroleum derivatives has recently been formed in France under the name Atlantique-Progil Electrochimie, with a capital of 100,000,000 francs.

The first board of directors will include representatives of the Société Industrielle des Dérivés de l'Acétylène, Société des Produits Chimiques de Clamecy, Société des Raffineries Françaises de Pétrole de l'Atlantique, Société Antar and Société Française des Pétroles Serco, as well as a number of other members.

AUSTRALIA

Domestic sulphur sources being developed

Pyrites deposits at Nairne, South Australia, are being developed, and the production of fertiliser from pyrites at Mount Morgan, Queensland, is being investigated following the Australian Government's plan for increasing domestic superphosphate production. The plan is reported to involve the replacement of imported sulphur by local sulphur-bearing materials for the manufacture of sulphuric acid, and the change from sulphur-burning plant to roasting plant for pyrites and other raw materials such as zinc concentrates. Large quantities of sulphur will be imported from America while the change-over is taking place.

Half of Australia's present sulphuric acid production depends on imported raw materials. A great increase in output will be necessary to fulfil the rising demand for superphosphate which is expected to reach 1,000,000 tons p.a. by 1960. Local sulphur-bearing materials include zinc concentrates from Broken Hill, New South Wales, pyrites from Mount Lyell, Tasmania, and Norseman, West Australia. Other potential sources include Mount Isa, Queensland, Captain's Flat, near Canberra, and Kalgoorlie, West Australia.

ARGENTINE

More citric acid

Commercial output of citric acid in Argentina at the Mago Industries de Fermentacion in Tucuman, which has been running at an average of 228,000 kg. annually during the early part of this year, is expected to rise soon to an average of 240,000 kg. annually, and to become sufficient to meet domestic requirements.

Commercial production of citric acid by the fermentation process, which was not started in Argentina until 1947, has been expanding rapidly. The local product has a rated purity of 99.8% and has been officially approved for use in the production of foodstuffs and pharmaceuticals.

JAPAN

Alcohol imports begin

Japan is to import alcohol for the first time since World War 2, in order to meet the increased demand for alcohol as one of the special procurement items related to the Korean war. Alcohol valued at $120,000 will be imported from Beira, Portuguese East Africa, under the July/September foreign currency budget.

PHILIPPINES

Brewery to make paper

In the semi-annual report of the San Miguel Brewery Inc., Manila, Col. Andres Soriano, president, reveals that the firm is contemplating an expansion into industrial lines such as the manufacture of paper and pulp, soda ash and derivatives.

In addition to the manufacture of beer and other light beverages, which are mainly exported to the U.S., San Miguel operates a glass plant and a corrugated carton factory.

BELGIAN CONGO

Cement plant planned

A new metallurgical cement factory, with an output of 25,000 to 30,000 tons a year and a capacity of double this figure, is to be built in Kakontwe. The capital for the project is being provided by four companies, one of which is Union Minière. The cement will be obtained by grinding cinders from the furnace of the Union Minière at Jadotville together with clinker and gypsum from portland cement. The cement, which is said to be similar to the normal portland cement, will not be exclusively used by Union Minière and some of it will be put on sale.

CANADA

New soda ash plant

Negotiations are reported to be under way for the construction of a soda ash plant in Antigonish, Nova Scotia. The deposits of salt and limestone, which were discovered following a survey of the province's chemical resources started last autumn, are said to amount to millions of tons of salt and 2,000,000 tons of high-quality limestone. The lateral limits of the formation have not yet been ascertained and exploration of the field is being intensified.

The plant will use coal from the Cape Breton or Pictou fields and will have an output of 200 tons daily and require an investment of $6,000,000 (Canadian). The possibilities for related industries were said to be reasonable in view of the abundance of salt deposits.

The only plant for the production of soda ash in Canada is at Amherstberg, Ontario.

Nylon chemicals plant

Canadian Industries Ltd. have announced that a factory to manufacture basic chemicals used in making nylon will be built on a 1,500-acre site between Brockville and Prescott, Ontario. Construction will begin this autumn and will be completed in the midsummer of 1953, it is stated. The factory would be the largest single project undertaken by the company and would make Canada self-sufficient in the two basic chemicals used in the manufacture of nylon yarn and staple fibre, eliminating dependence on U.S. sources.

The nylon-spinning factory at Kingston, 50 miles west, will be expanded to twice its present capacity to absorb the entire output of the new chemical factory.

INDIA

Technological institute opened

An important step towards the advancement of technical education in India was recently taken when Education Minister Maulana Azad opened the Indian Institute of Technology at Hijli, about 70 miles from Calcutta.

This institute is the first of four regional higher technological institutions proposed to be set up by the Central Government and will train students in the practical application of engineering science to industry. It will have provision for teaching 2,000 students at undergraduate level and 1,000 students for post-graduate study and research. The services of several professors from Western countries have been obtained, and four German professors have already joined the institute.

Inaugurating the institute, Maulana Azad said that with its opening fresh encouragement would be given to the improvement of technical education throughout the country. Though situated in one corner of India, it would cater for the needs of the country as a whole.

Maulana Azad said he looked forward to the day when facilities for technical education in India would be such as to attract people from abroad for higher scientific and technical training.

U.S.A.

Big new catalyst plant

One of the largest catalyst plants in the U.S. will be built by Davison Chemical Corp. The project, to be located on the Calcasieu River, six miles south of Lake Charles, will cost around $7,000,000. The site will provide space for production of other chemicals in addition to catalysts used in petroleum refining. Scheduled for operation early in 1952, the new plant will have facilities for producing synthetic fluid petroleum catalysts sufficient to process nearly 600,000 barrels daily of petroleum stocks, based on average refinery use of cracking catalysts. It will produce the micro-spheroidal type of synthetic silica-alumina catalyst. This form of catalyst is more nearly spherical and more uniform in particle size distribution than some other types and is preferred by many in the industry.

In addition to a new source of catalyst supply for the Gulf Coast area, the Lake Charles development will enable savings in transport of the finished product and some of the raw materials. The Gulf Coast area has had a tremendous expansion in the last few years, not only in petroleum

refining but also in chemical processing plants employing the end products of catalytic cracking. The new plant is part of a nation-wide effort by the industry to meet expanding defence and essential civilian requirements for petroleum products, such as high-octane petrol.

Anhydrous NH_3 plant to be built

A new synthetic anhydrous ammonia plant is to be constructed at Vicksburg, Miss., by the Spencer Chemical Co. The plant will cost about $14,000,000 and will have a designed capacity of 72,000 tons of anhydrous ammonia annually.

Overhaul of synthetic rubber plants urged

Modernisation of existing synthetic rubber producing plants and construction of new petroleum-base synthetic rubber facilities have been urged by Mr. Litchfield, chairman of the Goodyear Tire & Rubber Co. He said such action was necessary to avoid an excess of as much as 500,000 tons in rubber demand over supply by 1960.

He advised that expansion on a sufficient scale and under proper management would produce enough rubber to meet increasing demands and would bring the dangerous tendency toward prohibitive price levels in the market for natural rubber under control.

Mr. Litchfield proposed that new petroleum-base plants with a total capacity of 220,000 tons be built to replace present alcohol-base output of like capacity, in which the cost of producing GR-S synthetic rubber is considerably higher. He suggested that the alcohol-base plants be placed in inactive reserve for use 'only in time of great emergency when money cost is not a prime factor.'

A Goodyear official has disclosed that a new method involving additional cooling equipment would reduce by as much as half the cycle time of the blending of butadiene and styrene, the key step in synthetic production. This would permit a 50% increase in output of existing synthetic facilities, he claims.

Food preservation by atomic rays

Food preservation by atomic irradiation has been achieved on an experimental basis by University of Michigan researchers. Prof. E. Brownell of the College of Engineering, who is supervisor of the project, in reporting on it said several samples of raw beef had been exposed to the gamma rays without spoilage of odour or appreciable change in colour. Also subjected to the rays and now being studied are bananas, red plums, peaches, cherries, grapes, raspberries and bilberries.

Prof. Brownell said that normal methods of preservation—canning, freezing and refrigeration, drying and dehydration, smoking, salting and use of chemical preservatives—all tended to modify the flavour, texture and food value. In irradiation, milk, meat, fruit and vegetables are exposed to gamma rays emitted from a cobalt cylinder encased in a lead vault. This had destroyed or made inactive certain bacteria and enzymes which caused spoilage and decay in various perishable products, Prof. Brownell said.

New low-cost gas produced

A new method of producing heating gas at low cost from cheap fuels, including low-grade coals and heavy fuel oil, was described in a paper presented to the 12th International Congress of Pure and Applied Chemistry held recently in New York. The paper was read by Dr. Kurt Baum, Pan-European Industrial Plant Co., Paris.

The gas could be made from a wide range of raw materials, including peat, lignite, brown coals and sub-bituminous coals, he said. Even fuels high in ash content could be used. The high price of manufactured gas had been decisively influenced in the past by the price of the fuel used as raw material. Present methods of gasification are based on a high-quality fuel graded or specially prepared. By the new process any carbonaceous matter, or even heavy fuel oil, is reacted in suspension with air or oxygen and steam in an incomplete combustion method, very similar to ordinary combustion in a pulverised fuel burner, he explained.

The wide interest in such a process in France is based on new possibilities for the manufacture of cheap industrial heating gas, or the manufacture of synthetic gas for the chemical industry by the application of oxygen and steam, according to Dr. Baum.

Water in Industry

(*Concluded from page* 492)

with residual oxygen and maintain a concentration of 20 to 50 p.p.m. Na_2SO_3 in the boiler water.

(*c*) Protection of feed lines and economisers from corrosion by maintaining the *p*H value of the final feed at about 7.5. A small amount of caustic soda, or perhaps trisodium phosphate, can be added with the sodium sulphite, if tests show that additional alkali is required. If the feedwater is pure, the protection can be secured by recirculating some of the boiler water to the feed line.

(*d*) If corrosion in the boiler owing to concentrating caustic soda is suspected, the effect of replacing the alkalinity of the boiler water due to NaOH by a mixture of tri- and disodium phosphate could be tried.

(*e*) Reduction of ammonia in the feed by rejecting turbine condenser ejector drains.

(3) Blowdown to maintain the dissolved solids and silica contents of the boiler water at or below the limits required.

(4) The institution of a schedule of regular testing to observe and control the treatment at all stages.

The Science of Coal

A selection of reviews prepared for private circulation in the monthly bulletin of the British Coal Utilisation Research Association between 1943 and 1947 has been published in the form of a book,* edited by the late Dr. D. H. Bangham, when director of B.C.U.R.A. research laboratories, which presents up-to-date information in fields of coal chemistry and physics inadequately covered by existing textbooks. The contents are divided into five sections with a total of 26 reviews contributed by different authors.

The general rule followed in the arrangement of the subject matter has been to proceed from the general to the specialised. Part 1 covers modern experimental techniques and includes six reviews which deal with the applications of crystallography, absorption spectroscopy, mass spectrometry and photographic techniques in combustion research. Part 2 covers much ground common to other technologies where size reduction and the measurement of fine particles are involved. Four reviews on the constituents of coal, coal analysis and the presence of rare elements comprise Part 3. Part 4 is more specialised and contains five reviews on the organic chemistry of coal products, coal tar and hydrocarbon synthesis. Six reviews on chemical aspects of combustion and gasification form the final section, Part 5.

The choice of the papers published in this book has been made to appeal to a wide range of readers. Thus the book is suitable for students reading fuel technology either for a first degree or as a post-graduate study, for scientists in industry who wish to bring their reading up to date and, more especially, for the increasing number of workers in all countries engaged in the task of advancing the knowledge of coal and of its technology and utilisation.

* *Progress in Coal Science*, Vol. 1, edited by D. H. Bangham. Butterworth, London, 1950, pp. 456, including index and illustrations, 40s.

Super-fractionation apparatus. A most comprehensive booklet on commercial laboratory fractionating columns has been compiled by Griffin & Tatlock Ltd. It gives details of two types of columns, the 18 in. × 17 mm. column and the 5 ft. × 20 mm. column (length by diameter of packed section). They were developed during research work early in the war by the Anglo-Iranian Oil Co. and are now released for general sale. New fractionating column packings are also described. Fenske helices are of particular importance where an all-glass system is required in corrosive conditions. Dixon stainless steel gauze rings are required in the 1951 edition of the *S.T.P.T.C. Handbook*, under serial designation No. C.B. 8-50, for use in the distillation of crude benzole. Delivery of new orders for columns, complete on stands with control panels, is estimated at three to four months.

Meetings

Institution of Chemical Engineers

October 9. Discussion on 'Education of the Chemical Engineer by Part-Time Study,' 5.30 p.m., Geological Society, Burlington House, London, W.1.

October 20. 'Chemical Engineering and the Future,' by Sir Harold Hartley, 3 p.m., Reynolds Hall, College of Technology, Manchester.

October 20. 'Recovery of Sulphur Dioxide from Effluents obtained in Sulphuric Acid Manufacture,' by L. Moller, 3 p.m., Latin Theatre, the University, Edmund Street, Birmingham.

November 6. 'The Mechanism of the Drying of Solids with Special Reference to China Clay, Part 3,' by Prof. D. M. Newitt and M. Coleman, Geological Society, Burlington House, London, W.1.

S.C.I. Chemical Engineering Group

October 23. 'Some Sulphur Recovery Processes in Refinery Operations,' by G. M. Rowell, 5.30 p.m., Burlington House, London, W.1.

Chemical Society

October 11. 'Colour Photography,' by Dr. H. Baines, 7.15 p.m., Chemistry Lecture Theatre, the University, Sheffield. Joint meeting with the Royal Institute of Chemistry.

October 17. 'Microgram Analysis,' by Dr. C. L. Wilson, 7.15 p.m., Department of Agriculture, Queen's University, Belfast. Joint meeting with the Royal Institute of Chemistry and the Society of Chemical Industry.

October 18. Tilden lecture on 'Contributions of Wave Mechanics to Chemistry,' by Prof. C. A. Coulson, 7.30 p.m., Burlington House, Piccadilly, London, W.1.

October 18. 'Some Problems in the Oxidation of Hydrocarbons,' by Prof. A. R. Ubbelohde, 6.30 p.m., the University, Manchester. Joint meeting with the Royal Institute of Chemistry and the Society of Chemical Industry.

October 26. 'Some Aspects of Oxidation and Corrosion,' by Dr. U. R. Evans, 4.30 p.m., the University, Birmingham.

October 26. 'Chemicals as a Source of Energy with Special Reference to Industrial Applications and to Jet Propulsion,' by Dr. J. Taylor, 3.30 p.m., Chemistry Department, the University, Glasgow. Joint meeting with Alchemists' Club and Andersonian Chemical Society.

November 1. 'Some Newer Methods in Analytical Chemistry,' by R. Belcher, 7 p.m., Chemistry Department, the University, Bristol. Joint meeting with the Royal Institute of Chemistry and the Society of Chemical Industry.

Institution of Mechanical Engineers

October 18-19. Annual dinner and presidential address, Dorchester Hotel, London, W.1.

Institute of Fuel

October 16. 'Combustion Processes in Engines,' by Prof. F. H. Garner, 5.30 p.m., Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1.

October 17. 'Collection of Dust from Flue Gases,' by J. C. Cleeves, 2 p.m., Engineers' Club, Manchester. Joint meeting with the National Smoke Abatement Society.

Society of Chemical Industry

October 18. Road and Building Materials Group. 'The Durability of Tar and Tarmacadam,' by Dr. A. R. Lee and E. J. Dickinson, Road Research Laboratory, 6 p.m., Institution of Structural Engineers, 11 Upper Belgrave Street, London, S.W.1.

Oil and Colour Chemists' Association

October 23. 'Essential Oils,' by J. J. Nichols, 7.30 p.m., Hull Church Institute. Joint meeting with the Hull Chemical and Engineering Society.

November 5. 'Styrene Co-polymers,' by W. R. Moon, 7.30 p.m., Royal Station Hotel, Hull.

Institute of Metals

October 9. 'Metallurgical Problems of Atomic Energy,' by Dr. H. M. Finniston, 6.30 p.m., University College, Singleton Park, Swansea.

October 15. 'Radioactive Tracers in Metallurgy,' by Dr. H. M. Finniston, 6.30 p.m., The University, St. George's Square, Sheffield.

October 17. Discussion. 'Metal Economics.' *Session* 1. *Primary Resources of Ferrous and Non-Ferrous Metals.* (1) Chairman's Introduction by Prof. A. J. Murphy. (2) 'World Supply of Non-Ferrous Metals,' by R. Lewis Stubbs. (3) 'Metals as Natural Resources,' by Prof. S. Zuckerman. (4) 'Iron Ore,' by Dr. T. P. Colclough. *Session* 2. *Scrap Reclamation, Secondary Metals and Substitute Metals.* (5) 'Conservation of Metals,' by C. A. Bristow, A. J. Sidery and Dr. H. Sutton. (6) 'Economy by Standardisation,' by C. Dinsdale. (7) 'Influence of Specifications on Productivity,' by F. Hudson. (8) 'Secondary Heavy Metals,' by E. H. Jones. (9) 'Secondary Aluminium and Magnesium,' by Col. W. C. Devereux. 10 a.m. to 5 p.m., Park Lane Hotel, Piccadilly, London, W.1. Conversazione and Exhibition, 8 p.m., 4 Grosvenor Gardens, London, S.W.1.

Incorporated Plant Engineers

October 16. 'Fuels and Firing Appliances,' by Dr. E. G. Ritchie, 7 p.m., Engineering Centre, Sauchiehall Street, Glasgow.

October 17. 'Ultrasonic Testing in Plant and Maintenance Engineering,' by J. W. Fox, 7.15 p.m., Grand Hotel, Bristol.

October 26. 'Feed Water Treatment,' by B. Pocock, I.C.I. Ltd., 7.30 p.m., Imperial Hotel, Birmingham.

INTERNATIONAL CHEMICAL ENGINEERING

ENQUIRY BUREAU

17 Stratford Place, London W.1

Readers requiring names of suppliers of raw materials, machinery or finished products should complete this form and attach it to their business note-heading. Please state approximate quantities required.

We wish to know names and addresses of suppliers of the following:

_____

_____

_____

_____

_____

For office use only. No. Date

The Leonard Hill Technical Group

Articles published in some of our associated journals in the Leonard Hill Technical Group this month include:

Podophyllin and the Peltatins; Progress Reports on Cosmetics, Fertilisers and Chemotherapy—MANUFACTURING CHEMIST.

Catalytic Dehydrochlorination of Ethylene Dichloride; Refinery Expansion in Europe—PETROLEUM.

Paint Coating Thickness Meters; Canadian Raw Materials used in the Paint Industry—PAINT MANUFACTURE.

The Natal Sugar Industry; Potato Silage; Australian Wine Industry; Rehabilitation of Coconut Nurseries in Ceylon—WORLD CROPS.

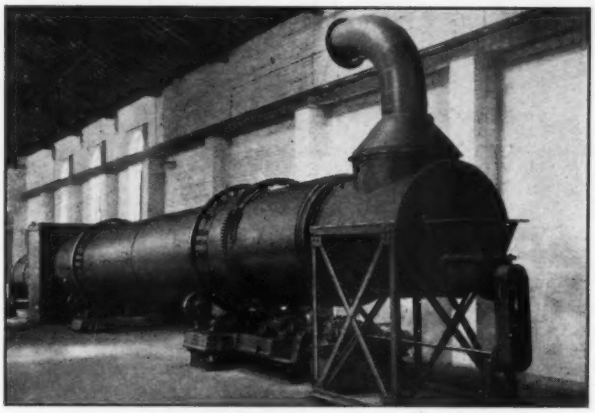
The Right Size of Excavator; The Selection of Earthmoving Plant for Public Works—MUCK SHIFTER.

Pottery in Northern Nigeria; A Galaxy of Glass (2)—POTTERY AND GLASS.

Industrial Roofing; A Report on the Building Research Congress—BUILDING DIGEST.

Textile Finishing, Use of Chemical Softening Agents—TEXTILE INDUSTRIES.

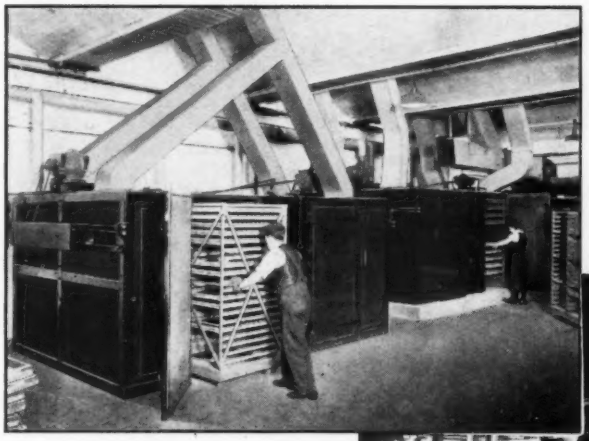
Mitchell DRYERS BUILT ON PRACTICAL EXPERIENCE!



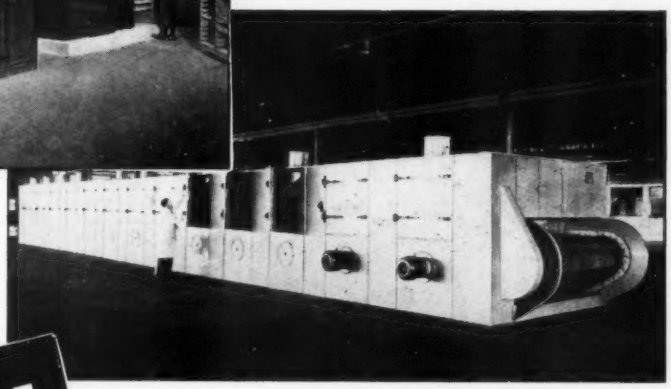
Above: Rotary dryer of the direct-heated type, with cylinder 50 ft. long, in the shops before despatch.

- *Highly efficient*
- *Maximum output*
- *Trouble-free operation*
- *Low maintenance and upkeep cost*
- *Reduction in floor space and drying period*

The need for industrial drying systems which are technically efficient, secure maximum output and give trouble-free operation, is met by Mitchell dryers; in use in many of the world's leading industrial works, offering rapid economical and uniform drying, with the subsequent speeding-up of production and increased output. This is the outcome of the constant research and practical experience which are behind every Mitchell dryer and drying system



Above: Illustration of Mitchell hot-air batch type drying stoves. Mitchell stoves are used throughout the Chemical and Process industries.



Above: Mitchell automatic continuous band type dryer.

Mitchell

L. A. MITCHELL LTD., 37 PETER STREET, MANCHESTER 2

INDUSTRIAL DRYING AND CHEMICAL ENGINEERS

WORKS: CARLISLE

MD. 36a

ROTAMETERS

FLOWMETERS FOR GASES AND LIQUIDS

REMOTE indicating, recording, controlling Rotameters supplied in various designs for use with small or large flows of gas or liquid at high pressures and temperatures.

Made in Bronze or Stainless Steel

LOW CONSTANT PRESSURE LOSS
10 : 1 SCALE RATIO

◆

Fullest details available on request. Write or phone CROydon 7262/3

ROTAMETER MFG. CO. LTD. PURLEY WAY · CROYDON · SURREY

INTERNATIONAL GLOSSARY

by Henri Rabaté

A Glossary of English, French and German technical terms used in the

Paint, Oil, Gum, Wax, Varnish, Printing Ink, Resin

and Allied Industries, arranged in three sections, totalling 137 pages

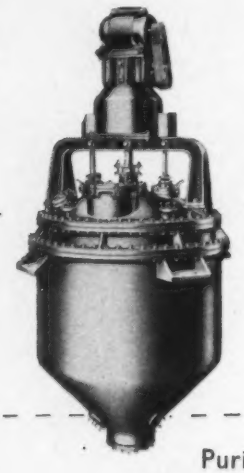
This book, of international repute, is indispensable to the paint man who wants to keep in touch with the industry in Europe and to follow international technical literature

Obtainable from: THE BOOK DEPARTMENT

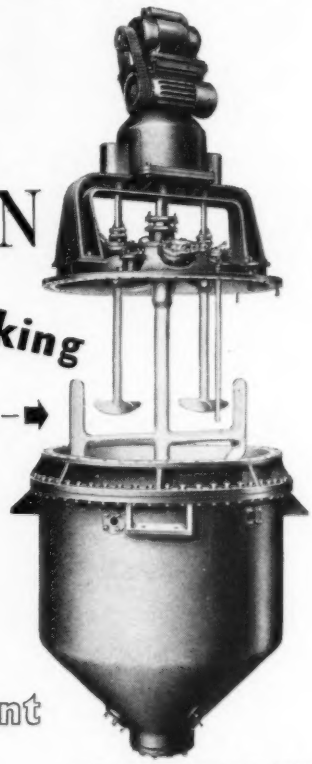
LEONARD HILL LIMITED

17 Stratford Place, London, W.1, England

PRICE IN GREAT BRITAIN 30/-: ELSEWHERE £2 ($6)



A REPUTATION *in the making*



Purity of product depends on quality of plant. Cannon Cast Iron vessels lined with acid-resisting glass enamel are used for many of Britain's purest products.

cannon Chemical Plant

Head Office and Works: Deepfields, Bilston, Staffs.
Telephone: Bilston 41241-5. *Telegrams:* "Cannon" Bilston

London Office: 57 Victoria St., S.W.1
Telephone: Abbey 2708 (2 lines)

ELECTROLYTIC

Copper Powder

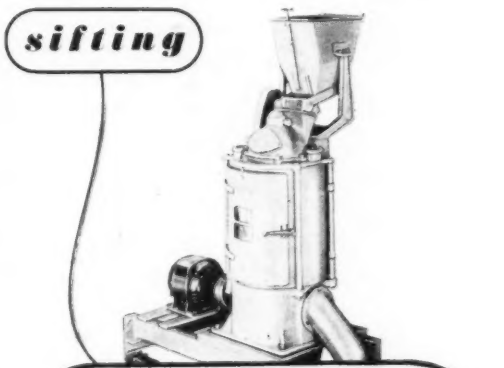
FOR ALL PURPOSES
IN VARIOUS GRADES
OR MADE TO CUSTOMERS
OWN REQUIREMENTS

Manufactured by the **PIONEERS** in Great Britain

J. & J. MAKIN (METALS) **LTD**

Room 57, Grosvenor Chambers, 16 Deansgate
Manchester, 3

sifting



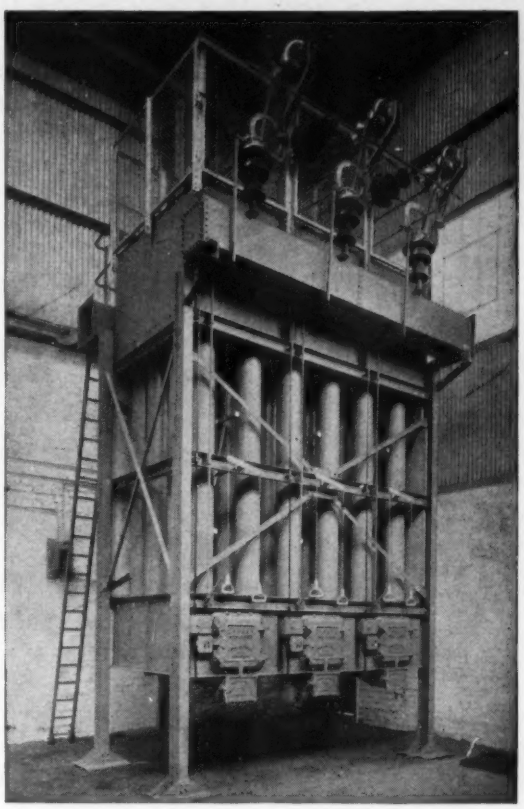
PASCALL

sifters have years of experience of sifting behind their design. Our experience of sifting covers a wide range of materials. Let us help you with your problem. Tests undertaken on your material and technical data supplied free of charge.

Outputs range from tons to lbs. per hour

Write for list 1910
Tel : Paddington 7236

THE PASCALL ENGINEERING CO., LTD., 114, LISSON GROVE, LONDON, N.W.1



ELECTROFILTERS

as supplied to refineries for the recovery of

GOLD and SILVER

Plants supplied for the Precipitation of all industrial

DUSTS, MISTS and FUMES

Multi-unit installations for

P.F. FIRED BOILERS
BLAST FURNACES
CEMENT PLANTS

LODGE-COTTRELL Ltd

Telephone : Central 7714

George Street Parade, Birmingham, 3

new edition

THE CHEMICAL SENSES

By R. W. Moncrieff

538 pages *21s. 11d. post free*

The Chemical Senses—their part in Life. Structure of the Chemical Sense Organs and their Connections. Sensation. Olfaction. Gustation. The Common Chemical Sense. Chemical Sensibility in Lower Animals. Classification of Odours. Chemical Constitution and Odour. Taste and Constitution. The Properties of Odorous Materials. Theories of Odour. Perfumes and Essences. Flavour and Food. Glossary. Bibliography. Author and Subject Indices.

COSMETIC MATERIALS

By R. G. Harry, F.R.I.C.

479 pages *Illustrated* *35s. 11d. post free*

THE CANADIAN PHARMACEUTICAL JOURNAL: *'Mr. Harry ... has prepared in the present volume a kind of B.P. for the manufacture of cosmetics and allied products.'*
MANUFACTURING CHEMIST: *'One can have nothing but admiration for the manner in which the author has tackled this extremely difficult and controversial subject.'*
SOAP, PERFUMERY AND COSMETICS: *'It is a work of first-rate importance, and no self-respecting cosmetic manufacturer, buyer or chemist can afford to be without it.'*

TECHNIQUE OF BEAUTY PRODUCTS *Translated from the French by 'A.R.I.C.'*

178 pages *18s. 4d. post free*

ÆSTHETIC PHYSIOLOGY: *Beauty. Æsthetic Hygiene. Types of Skin. Morphology. The Skin as Protein Gel. pH of the Skin. Reactions of the Skin to External Agents and Endogenous Excitations.*
BEAUTY PRODUCTS: *Cosmetic Excipients. True and Pseudo or Colloidal Solutions. Emulsions with Carbohydrate Base. Lamellar Stearic Emulsions. Dispersions. Suspension. Solid Products. Microscopic Study of Cosmetics. Measurement of Hardness of Cosmetic Products.*
SOME RAW MATERIALS OF THE COSMETICOLOGIST: *Pure, Soft and Electro-Osmotic Water-Glycols. Vitaminised Oils, Iso-linoleic Acid. Raw Materials for Gels. Colloids and Emulsions; Fatty Acids, Alkaline Stearates, Fatty Alcohols, Fatty Acid Esters, Triethanolamine, Lecithin, Cholesterol and Lecithin, Waxes, Vaselines and Vaso-Sterols, Bentonites, Titanium White.*
MANUFACTURE OF BEAUTY PRODUCTS: *Lotions. Face Milks. Deodorants. Astringents. Cleansing Products. Face Powders. Beauty Oils. Creams. Rouges. Pigments. Eye and Eyelash Make-up. Beauty Masks or Packs.*
ÆSTHETIC DERMATOLOGY: *Vitamin Therapy. Opo-Therapy. Hormone Therapy. Aroma-Therapy. Physico-Chemical Properties of Aromatics. Sulpho-Therapy. Conclusions.*

CHEMICAL INDUSTRIES

Edited by Dr. E. N. Tiratsoo

22nd edition now published *450 pages* *31s. post free*

Commercial Indices. Constructional Materials. Fuels and Steam Raising. Power Production and Transmission. Refrigeration. Water Treatment. Chemical Plant. Handling, Conveying, Transport. Industrial and Scientific Instruments. Glossary of Industrial Chemicals. Fine Chemicals. Chemical and Physical Tables. Mathematical and Conversion Tables.

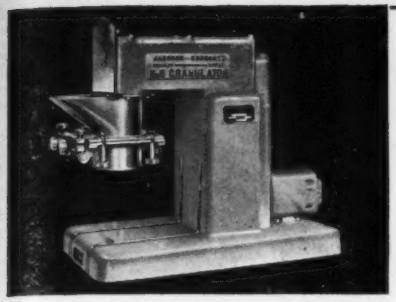
MODERN COSMETICOLOGY

By R. G. Harry, F.R.I.C.

2nd edition reprinted 1951 *432 pages* *35s. 11d. post free*

Contents—Introduction. Histology of the Skin. Emulsions. Cleansing Creams, Milks and Lotions. Acid Creams, Milks and Lotions. Face Packs and Masks, Mud Creams, etc. Vanishing Creams. Powder Creams. Skin Nutrition. Skin Foods or Lubricating Creams. Astringent Lotions and Skin Tonics. Lipstick. Make-up Preparations. Face Powders. Sunburn and Suntan Preparations. Deodorants. Depilatories. Allergy and Dermatitis. Antioxidants. Preservation of Cosmetic Creams and Lotions. Bath Preparations. Bath Oils and Emulsions. Foam Baths. Hand Creams and Lotions. Histology of the Tooth, including Pathological Dental Conditions. Dental Preparations. Mouth-washes. Shaving Preparations. Histology of the Hair. Hair Tonics and Solutions. Hair Setting Lotions and Hair Lacquers. Hair Shampoos and Soapless Detergents. Histology of the Nail. Manicure Preparations. Eye Lotions. Baby Preparations. Food Preparations. Insect Bite Preparations. Humectants. Acne Preparations. Colouring of Cosmetic and Toilet Preparants. Application of Cosmetics. Diet and Skin Health. Chemical Examination of Cosmetic and Toilet Preparations. 'Modus Operandi.' Appendices. Index. Illustrated with black and white and coloured photographs.

LEONARD HILL LIMITED, 17 STRATFORD PLACE, W.1



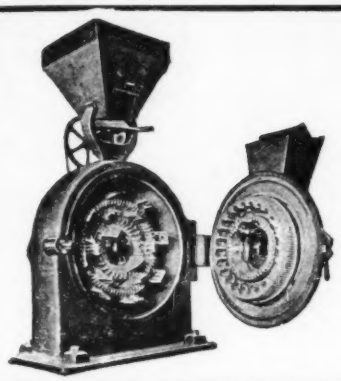
No. 6 Laboratory Granulator

Also:
Dry Type Granulators
Reciprocating Granulators
Filling and Packing Machines

J. G. JACKSON & CROCKATT LTD
NITSHILL ROAD · THORNLIEBANK · GLASGOW
Telephone: Giffnock 391 Telegrams: "JAKCRO" Thornliebank

weighing
filling
sealing
of
POWDERS, DRY GOODS, LIQUID AMPOULES, etc.

AUTOMATIC WEIGHING AND PACKING MACHINE CO.
(Proprietor: ARTHUR R. SMITH)
Caroline Street, Birmingham 3, England
Export Enquiries Invited



THE PULMAC MILL

For producing the best results in the reduction of all Dry materials to the desired mesh in one operation

INTERNATIONAL PULVERISERS LIMITED

'Phone: Victoria 2958

70 VICTORIA STREET
LONDON, S.W.1, ENGLAND

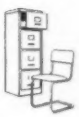
'Grams: "Pulgrind" Sowest London

Start Finishing by **JENOLIZING**

THE ONLY PROCESS WHICH WILL SIMULTANEOUSLY
★ Completely remove rust and scale
★ Neutralize against re-rusting
★ Provide a phosphate coating
★ Bind paint to metal

JENOLIZE AND ECONOMISE

Save Metal, Save Money, Save Labour with—
JENOLITE RUST REMOVER AND NEUTRALIZER



Other "Jenolite" Products:—
Aluminium Keying Solution, Metal Degreasers, Soldering Solutions, Aluminium Degreaser, Paint Strippers, Heavy Scale Remover, Black Finish Salt.

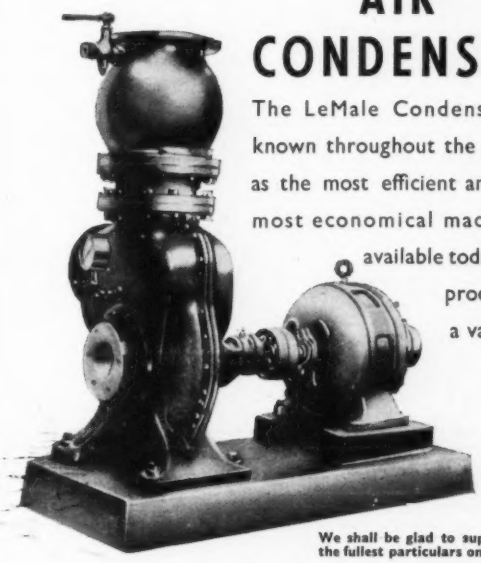
JENOLIZE ALUMINIUM BEFORE PAINTING!

Jenolite

Manufacturers of Chemicals for Metal Treatment

Write for further particulars to Dept. 151
JENOLITE LIMITED, 43 Piazza Chambers, Covent Garden, London, W.C.2. *Telephone: TEMple Bar 1745, 3058 and 5059*
Scottish enquiries to JENOLITE (Scotland) LTD., 304 High St., Glasgow, C.4. *Tel.: Bell 2438/9*

LEMALE EJECTO AIR CONDENSER



The LeMale Condenser is known throughout the world as the most efficient and the most economical machine, available today, for producing a vacuum

We shall be glad to supply you the fullest particulars on request

MACHINERY (CONTINENTAL) LTD.
175 BROMPTON ROAD LONDON S.W.3.
TELEPHONE: KENSINGTON 6228 (3 LINES)

o.h.

CLASSIFIED ADVERTISEMENTS

MUST BE PREPAID

3d. a word, minimum 4s. Box number 1s. extra

Replies to BOX Numbers

should be addressed to

International Chemical Engineering, **17 Stratford Place, W.1**

SEMI-DISPLAY RATES ON REQUEST

SITUATIONS VACANT

UNEQUALLED postal instruction in Chemical Engineering (General Chemistry, Chemical Technology, Principles of Iron and Steel Manufacture, Inorganic and Organic Chemistry, Fuel Technology) is offered by the I.C.S., world's largest and greatest school teaching by the correspondence method. There is also a Course in Chemical Works Management. Our instruction is backed by 59 years of successful experience. Let us send you a copy of our special booklet, 'Chemical Engineering.' It is packed with information on how to win promotion and better pay. Write for it today. It is free. So are the willing services of our Advisory Department.—International Correspondence Schools, Ltd., Dept. 326, International Buildings, Kingsway, London.

SEVERAL VACANCIES exist in progressive industrial research and development department for young SCIENTISTS with an industrial research outlook and preferably some experience in one or more of the following lines: Ceramics, refractories, and synthetic resins. State age, qualifications, experience and salary required. —Replies to Technical Manager, the Carborundum Co. Ltd., Trafford Park, Manchester 17.

FOR SALE

Four Copper Stills, steam heated with water-jacketed columns, condensers and constant level. Capacity 1,000 gallons. In first class condition. Specifications and drawing on request.

REED BROTHERS (ENGINEERING) LTD.
REPLANT WORKS, CUBA STREET, MILLWALL, E.14
Phone: EAST 4081

U.S. FIRM NEEDS CHEMICALS

CADMIUM METAL
CADMIUM SALTS
SODIUM CYANIDE
COPPER CYANIDE
POTASSIUM CYANIDE
NICKEL SALTS

Send Offers of 1-20 Tons to:

ACETO CHEMICAL CO., INC.
82 Beaver Street, New York 5, N.Y.

WANTED

WANTED—Woolgrease, any quantities, any grade. Submit samples with quotations to William Laing Ltd., Central Chambers, Cheapside, Bradford, Yorkshire, quoting reference ESL.

WE pay the highest prices obtainable in this country for used 40/45-gal. drums in sound condition. Immediate collection.—Process Salvage Ltd., 79-83 Coborn Road, London, E.3. Telephone Advance 1676.

CASH for scrap metals, etc. Write or phone Bow Scrap & Salvage, Furze Street, Bow, E.3. East 4510.

WANTED—10/15 tons short asbestos fibre, samples required. ½ ton cleaned sorts Kordofan gum arabic. —C. W. Longney, Oxford Chambers, St. Stephen's Street, Bristol 1.

REQUIRED urgently either second-hand in good condition or new, 30-40 cu. ft. wash-type timber or cast-iron filter press, with air-blowing attachment. Details to British Schering Mfg. Labs. Ltd., Hazel Grove, Cheshire.

WANTED REGULARLY for treatment in our own works. Residues containing cadmium, copper, tin, zinc, lead, nickel. Offers to Oakland Metal Co. Ltd., Oakland Works, Willington, Derby. Telephone No.: Repton 391/392.

MISCELLANEOUS SALES

GLASSBLOWING, repetition and scientific, by Hall Drysdale & Co. Ltd., of 58 Commerce Road, Wood Green, London, N.22. Phone, BOWes Park 7221-2.

DOHM, LTD., crush, pulverise, grind and grade raw materials everywhere; factories in main industrial centres.—Please send your enquiries to 167 Victoria Street, London, S.W.1. Victoria 1414.

INDUSTRIAL BOOK SERVICE (Abacus) LIMITED

- *We stock a number of technical and scientific publications on chemistry and the chemical industries. A list will be sent on request. Please send your enquiries for books on any technical subject to:*

18 Stratford Place
LONDON - W.1

CLASSIFIED ADVERTISEMENTS

will not appear unless payment is made by the 17th of the month preceding publication

MISCELLANEOUS SALES

(continued)

LABORATORY Test Sieves to B.S. 410:43 or commercial quality; ring or write for brochure.—Endecotts (Filters), Ltd., 251 Kingston Road, London, S.W.19, Liberty 8121/2.

BUSINESS OPPORTUNITIES

PULVERISING, grinding, mixing, drying. We collect and deliver. Crack Pulverising Mills Ltd., Plantation House, Mincing Lane, E.C.3.

AMERICA'S famous magazines. One year's supply *Modern Plastics*, 35s.; *Chemical Engineering*, 10s. Free booklet listing all others sent on request.—Willen, Ltd. (Dept. 48), 101 Fleet Street, London, E.C.4.

TRANSLATIONS

TRANSLATIONS, technical, scientific, French, German, etc., by highly qualified graduate engineers-scientists, speciality difficult translations.—Smuts Technical Services, 8 Palace Gates Road, London, N.22.

MISCELLANEOUS

TRAILERS.—Ex-Govt. pre-selection stock, 30 cwt to 20 tons carrying capacity. Unused; equal to new We have supplied thousands of satisfied customers throughout the U.K. and abroad. In reply please state carrying capacity and body lengths required.—Cartruk Ltd., Trailer Distributors, 76 Wellington Road South, Stockport.

GRINDING, mixing, sifting. We have facilities for grinding, mixing and sifting a wide range of materials in modern plant of large capacity. No risk of contamination, as we do not handle dirty or objectionable substances.—Oury Millar & Co., Ltd., Thames House, Queen Street Place, London, E.C.4.

ANALYSIS.—Rapid Routine Analysis. Specialised Analysis. Ultimate Analysis. Assays. All Assays according to British Pharmacopoeia and Codex.—Write for particulars to Newchem Ltd., Poynton, Cheshire.

PATENT No. 500201 for 'Improvements in or relating to the Recovery of Stabilised Gasoline from Vapours produced in Cracking Hydrocarbons.' Owners desire to meet all demands for the utilisation of this patent and invite enquiries from manufacturers in Great Britain prepared to assist in its commercial exploitation.—Address in first instance Messrs. Pollak, Mercer & Tench, Chartered Patent Agents, 134 Cheapside, London, E.C.2.

WE buy and sell Heavy Chemicals and allied articles.—CECIL FARMS, LTD., 53 Tottenham Court Road, London, W.1. Telephone: LANgham 2499.

CLASSIFIED ADVERTISEMENT ORDER FORM

INTERNATIONAL CHEMICAL ENGINEERING
17 STRATFORD PLACE, W.1
Phone: MAYfair 7383

Please insert our Advertisement/s as under, in next available issue

★ **BLOCK LETTERS AVOID ERRORS** ★

All advertisements must be prepaid

CHARGES:
3d. a WORD. Minimum 4/-. Box Numbers 1/- extra

Insert your name and address here if Box Number required

Name .....

Address .....

.....